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Effect of Oxygenation Therapy on Increasing Arterial Oxygen Tension in Hypoxemic Patients with Stable Chronic Obstructive Pulmonary Disease while Breathing Ambient Air—WJ O'Donohue Jr. Chest 1991;100:968.

Recertification for long-term oxygen therapy (LTOT) has been recommended for patients who are clinically unstable when home oxygen therapy is begun. Periods of observation for clinical stability have ranged from 3 weeks to 3 months in large multicenter clinical trials. There is concern, however, that an increase in arterial oxygen tension occurring after 3 months may be related to the beneficial effects of oxygen rather than to continued changes in clinical stability. In a review of 20 patients receiving transtracheal oxygen (TTO_2) therapy, it was found that 4 (20%) did not qualify for oxygen therapy at the end of 6 months because the P_{aO_2} breathing ambient air had increased to levels above 55 torr. All patients were clinically stable at the time of insertion of the transtracheal catheter and all had been receiving nasal oxygen for at least 7 months (mean 25.8 months) before entering the study. A retrospective analysis of the data published by Weitzenblum at al disclosed that 4 (25%) of 16 patients had a similar increase in P_{aO_2} when re-examined after 1 year of oxygen therapy. All of the patients had been studied at least 1 year before oxygen therapy was initiated and each had three consecutive arterial blood gas measurements done monthly to ensure clinical stability. The increase in P_{aO_2} to levels above 55 torr observed in patients receiving TTO_2 therapy was associated with a reduction in alveolar-arterial oxygen gradient; however, arterial oxygen desaturation with walking persisted. The specific mechanisms for improvement in P_{aO_2} during oxygen therapy require further study. Any recommendation for recertification of LTOT must recognize that an increase in P_{aO_2} after 3 months may be due to the beneficial effects of the oxygen therapy and does not provide prima facie justification for termination of therapy.

High-Volume, Low-Pressure Cuffs: Are They Always Low Pressure?—D Guyton, MJ Banner, RR Kirby. Chest 1991;100:1076.

Ischemic tracheal complications due to the ETT cuff occur in approximately 10% of mechanically ventilated critically ill patients despite the use of high-volume, low-pressure ETT cuffs. Using a laboratory model, we studied the effects of airway pressure on three different ETT cuff designs, including two "low pressure" designs. Positive airway pressure acted on the "low pressure" cuffs to create a "self-sealing" effect that maintained tracheal occlusion despite airway pressure that exceeded cuff inflation pressure. Increases in airway pressure caused by decreased lung compliance resulted in higher cuff inflation pressures in all three groups, with the smallest increase occurring in the design that had the longest tracheal contact length. We conclude that the current high-volume, low-pressure ETT cuff design currently used does not guarantee low cuff pressure when high airway pressures occur, and an alternative design should be developed.

A Computer-Controlled Ventilator Weaning System—JH Strickland Jr, JH Hasson. Chest 1991;100:1096.

Weaning of patients from mechanical ventilation is a time-consuming, labor-intensive process. Because most weaning decisions are based on objective data, we tested a computer-directed weaning system on postoperative patients. We developed an automatic, computer-controlled ventilator weaning system that interfaces a laptop computer to a ventilator and a pulse oximeter. The laptop computer program accesses patient data through the ventilator and pulse oximeter to make weaning decisions. The computer directly controls the ventilator through an interface developed for this system. We tested the system in 9 postoperative patients who met the following criteria: negative inspiratory force ≤ -20 cm H_2O, vital capacity > 10 mL/kg, inspired oxygen concentration $\leq 40\%$, and satisfactory arterial blood gas parameters (pH between 7.32 and 7.48, P_{CO_2} between 32 and 48, and oxygen saturation $\geq 90\%$). The computer decreased the SIMV rate by 2 breaths/min every 5 min until a rate of 2 breaths/min was reached, then decreased pressure support by 4 cm H_2O every 5 min as long as the patient met the following criteria: respiratory rate between 8 and 25 breaths/min, minute ventilation between 6 and 14 L, and pulse oximeter oxygen saturation $\geq 90\%$. If unsatisfactory weaning criteria were noted, the system automatically returned the patient to the previous weaning level. We successfully weaned 9 patients using the system. Additional studies are underway to determine if this system can be used in medical patients. We believe this computer-controlled ventilator weaning system can be used successfully in patients requiring mechanical ventilation and may decrease the time and rest associated with the care of these patients.

Comparison of Inspiratory Work of Breathing in T-Piece Breathing, PSV, and Pleural Pressure Support Ventilation (PPSV)—T Tak-

Everything You Want to Know About Ventilation

Monitoring Respiratory Mechanics During Mechanical Ventilation

By Robert L. Chatburn, RRT. Explains how physical and mathematical models are developed and applied, how such models are incorporated into ventilator design to provide estimates of mechanics, and some of the problems that can develop because of the limitations of the models. He discusses the mechanics-monitoring capabilities of the Bear 5, Puritan-Bennett 7200, Hamilton Veolar, and the Siemens 940 'add-on.'

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Pressure Support Update

By Neil MacIntyre, MD. Briefly reviews what pressure support ventilation (PSV) is and how it is now used. Explains waveforms for airway pressure, flow, and volume, illustrates the measurement of inspiratory muscle loads by pressure-time index and muscle VO2, and demonstrates how muscle efficiency changes as the character of work changes. Includes examples of clinical applications of low- and high-level PSV for elimination of the imposed work of breathing and as a weaning tool.

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Managing the Work of Breathing During Mechanical Ventilation

By John Marini, MD. Learn about the work of breathing and ways in which it can be minimized in the clinical settings on patients receiving mechanical ventilation. The focus of this presentation is on diminishing the breathing work load through quantifying the effort during mechanical ventilation via direct measures such as oxygen consumption, electromyography, pressure-time index, and external work of breathing and indirect measures such as breathing patterns and dyspnea.

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Theory and Application of Neonatal Ventilation

By Robert Chatburn, RRT. Knob-turning in the neonatal intensive care unit should be a profound activity because it often has profound consequences. Adjustment of a single control on a ventilator generally has multiple effects, and thorough consideration of how controls are interrelated is essential for optimum care. Presents a well-organized and systemic approach for managing mechanical ventilation.

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Modes of Conventional Ventilation

By Robert M. Kacmarek, PhD, RRT. An historical review of mechanical ventilation is presented, including the rationale for movement from one generation of ventilators to another. Ventilator modes discussed include control, assist/control (A/C), intermittent mandatory ventilation (IMV), synchronized intermittent mandatory ventilation (SIMV), mandatory minute ventilation (MMV), and pressure support ventilation (PSV). Description includes typical pressure waveforms of each mode.

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Pressure Support Ventilation

By Neil MacIntyre, MD. This video presentation defines and describes the physiological considerations attributed to pressure support ventilation (PSV) and the clinical situations when PSV may be useful. Includes comparisons when low pressure levels and high pressure levels of PSV are offered. Discussion includes using PSV to help overcome resistance for intubated patients and as an augmented ventilatory mode of weaning. Also included are results of patient weaning trials with and without PSV.

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ahashi, J Takezawa, T Kimura, K Nishiwaki, Y Shimada. Chest 1991; 100:1030.

We have compared the inspiratory work of breathing during T-piece breathing, pressure support ventilation (PSV), and pleural pressure support ventilation (PPSV) by using a lung model with variable compliance and resistance, under simulated spontaneous breathing. Our lung model consists of two spring-loaded bellows, representing the lung and diaphragm, placed in an airtight container. Inspiration begins with the withdrawal of air from the diaphragm bellows by a time-cycled jet-flow-creating Venturi mechanism. Expiration occurs by opening the diaphragm bellows to the atmosphere. Work of breathing (WOB) is calculated by plotting the pressure-volume curve, with pressure corresponding to intrabox pressure and volume corresponding to the total volume; PPSV is a new mode of mechanical ventilatory support accomplished by setting the ventilator (Servo 900C) into the PSV mode with a level of 0 cm H_2O, using the pleural pressure as the input and target signal. The PPSV maximally reduces WOB under any circumstances. The PSV sufficiently reduced WOB only in the normal lung and the lung with low compliance; however, a pressure supporting time is diminished in the lung with low compliance. The serious limitations of PSV remain in its application to the lung with high resistance. It is concluded that PPSV is closer to the actual patient's signal and has a potential advantage in reducing WOB in the lung with low compliance or high resistance (or both). The lung with flow limitation is still a challenging issue for mech-anical ventilatory assistance.

Anti-Inflammatory Therapy for Acute Lung Injury: A Review of Animal and Clinical Studies—C Metz, WJ Sibbald. Chest 1991;100: 1110.

The adult respiratory distress syndrome (ARDS) continues to demonstrate high mortality. This syndrome is frequently observed as a remote complication of another disease process and is characterized by a significant inflammatory component. The purpose of this review is to compare and contrast published research on the use of anti-inflammatory agents, steroidal and nonsteroidal, in animal models of acute lung injury. Emphasis is given to the nature of the experimental pulmonary injury, infusion (ie, oleic acid and zymosan-activated plasma) or bacteriologically (ie, endotoxin and live bacteria) induced and the timing of drug administration relative to induction of the insult. The clinical data available on the use of these drugs in ARDS are discussed, and a rationale is presented for future clinical trials in these patients.

Acceptance of CPAP Therapy for Sleep Apnea—H Rauscher, W Popp, T Wanke, H Zwick. Chest 1991;100: 1019.

Although NCPAP is the most efficient nonsurgical treatment for patients with OSA, many patients do not accept sleeping with the nose mask. To determine the factors influencing acceptance, treatment with NCPAP was offered to 95 patients with an apnea plus hypopnea index (AHI) greater than 15. After the first night on NCPAP, 47 of 65 patients decided to have NCPAP as a home therapy. Excessive daytime sleepiness was more frequently reported by acceptors than refusers. The frequency of complaints about psychomental symptoms such as poor mental performance and bad memory, was not different between the two groups. There was a close correlation between the rate of acceptance and the AHI as well as the number of positive answers to questions about symptoms of daytime sleepiness in a questionnaire, which correlated with the number and length of apneas. Acceptance of NCPAP was found to be dependent on the subjective feeling of impairment by hypersomnolence due to OSA.

Measuring the Quality of Well-Being in Cystic Fibrosis and Lung Transplation: The Importance of the Area under the Curve—DM Orenstein, RM Kaplan. Chest 1991; 100:1016.

The quality of well-being scale (QWB) has been used to measure overall life quality in a number of different clinical conditions, including cystic fibrosis and chronic obstructive pulmonary disease. Evidence supports its validity and reliability in both cross-sectional and longitudinal studies. One of the strengths of the QWB is that it is not organ-specific, so that it can take into account the broad impact of a disease and/or intervention, including unanticipated effects. The well-year of life is a concept that includes both morbidity and mortality: If a disease reduces quality of life by one-half, over a period of two years, that person can be said to have lost one full well-year. As we examine the impact of diseases such as cystic fibrosis, and of interventions such as lung transplantation, it is important to consider changes in overall well-being over time to help individual patients and families make difficult therapeutic choices and to help formulate health policy.

Frequency Spectra of Normal Breath Sounds in Childhood—HA Hidalgo, MJ Wegmann, WW Waring. Chest 1991;100:999.

Clinicians who auscultate the chest of normal children note that the frequency content of their breath

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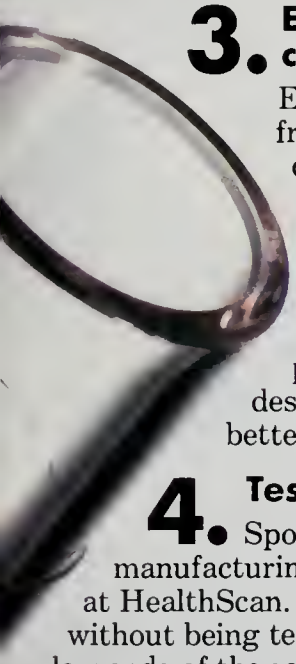
We started out competing against other peak flow meters. Now that we're the leader, we compete against ourselves. In the last two years alone, we've made more than 10 separate product improvements...with more still on the drawing boards.

2. Develop a patented design

ASSESS® and ASSESS Low Range use a unique flow-sampling technology that minimizes wear and delivers superior accuracy, reproducibility, and consistency. How consistent? After two years of simulated daily use, a recent independent research study found no more than 1% variability.[1]

3. Engineer it without compromise



Everything about ASSESS from its easy-to-use design...to its easy-to-read scale...to its transparent construction that encourages regular cleaning...to its virtually indestructible polycarbonate body—is designed to make it work better and last longer.

4. Test every unit

Spot-checking is the norm in manufacturing quality control. Not at HealthScan. *No* unit leaves our plant without being tested at both the high and low ends of the scale. (Plus, every hour we select ten random samples for even more rigorous statistical quality control.)

5. Put it to the test in the laboratory

Recently, researchers at Montefiore Medical Center measured ASSESS against our leading competitor. Their findings? The accuracy of the other product deteriorated after only two months of simulated use. But ASSESS kept on delivering consistently accurate readings.[2]

6. Put it to the test in clinical practice

Lab results like this say a lot about ASSESS. Our clinical acceptance says even more. Nine out of every ten peak flow meters used in hospitals are ASSESS.[1] Why? Read on.

7. Support physicians

Physicians know they can count on us, not just for a superior product but for superior service—including extensive patient education materials, a dedicated professional services department, and the only comprehensive peak flow monitoring system.

8. Support patients and their families

We don't *have* to donate hundreds of units every year to asthma camps across America. Or back ASSESS with an *unlimited* one-year warranty. Or make a special Braille unit for blind patients. Or provide patient instructions in other languages. We just figure it's the responsibility of a leader.

9. Invite criticism

With all these efforts, you might think we'd hate to hear complaints about ASSESS. Just the opposite. Frank feedback from physicians and patients only helps us make ASSESS better. Which is why we encourage that feedback with a toll-free telephone hotline.

10. Go back to step 1

We're proud of our leadership... but we're not satisfied. So we'll keep on making improvements. We expect more of ASSESS. You should too.

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ASSESS® Peak Flow Meter

STANDARD RANGE 60 to 880 L/min
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Setting the standard for peak flow monitoring.

References 1 Data on file, HealthScan Products Inc. 2 Shapiro S, Hendler J, Ogirala R, et al An evaluation of the accuracy of Assess and MiniWright peak flowmeters. *Chest* 99:358-362, 1991

ASSESS and ASSESS Low Range meet *National Asthma Education Program Technical Standards for Peak Flow Meters*, January, 1991. AA710001-0 10/91

HealthScan Products Inc., 908 Pompton Avenue, Cedar Grove, NJ 07009-1292 **Circle 148 on reader service card**

sounds appears to vary with age. Because these changes have not been systematically documented before, we recorded and analyzed inspiratory breath sounds in 35 children (0 to 13 years) and 5 adults (34 to 43 years). Our objective was to determine if the frequency content of normal breath sounds differed with age. Using a Fast Fourier Transform program, we calculated an average am-plitude frequency spectrum from the inspiratory portion of the breath sounds of each subject (n = 10 breaths), and we compared the shape of the AFS and the values of selected frequency parameters. We found that the shape of the AFS of the youngest children differed most from the AFS of adults. Three of four selected frequency parameters (F25, F50, F95) differed significantly between children and adults ($p < 0.05$), and one parameter (F75) did not ($p = 0.11$). The F25, F50, and F75 parameters of children (but not F95) were correlated ($p < 0.001$) with increasing height and age. These results suggest that differences in the frequency content of the normal breath sounds of children and adults contribute to the differences that clinicians detect during clinical auscultation.

Relation between Airway Responsiveness and Serum IgE in Children with Asthma and in Apparently Normal Children—MR Sears, B Burrows, EM Flannery, GP Herbison, CK Hewitt, MD Holdaway. N Engl J Med 1991;325:1067.

BACKGROUND: Although asthma diagnosed by a physician is known to be related to serum IgE levels, it is not known whether there is a relation between the level of IgE and airway hyperresponsiveness to a methacholine challenge. The characteristics of asymptomatic persons that predispose them to airway hyperrsponsiveness are also unknown. METHODS: We studied the relation between the serum total IgE level and airway hyperresponsiveness in the presence or absence of asthma and other atopic diseases in a birth cohort of children. Data from a questionnaire regarding respiratory symptoms, plus measurements of the ser-um total IgE level and airway responsiveness to inhaled methacho-line, were obtained for 562 11-year-olds in New Zealand. RESULTS: The boys had a higher prevalence than the girls of current diagnosed asthma (13% vs 6%), current symptoms of wheezing (22% vs 15%) and airflow obstruction at base line (6% vs 1%), and had a wider distribution of IgE levels, although mean IgE levels (120.8 IU per mL in the boys and 98.1 IU per mL in the girls) did not differ significantly between the sexes. The prevalence of diagnosed asthma was

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- **Results are long lasting[†]**
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[1,†] Wm. Shearouse RRT. "The Use of Respiratory Biofeedback in Respiratory Disease": Respiratory Care, Nov. 1991.

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PMP's Prefil® Adjustable Electronic Aerosol Heater can deliver aerosol at body temperature--even at a 28% FIO_2 setting.

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A sensor probe attached to the heater and to the circuit at the patient airway constantly monitors the proximal airway temperature and feeds that information back to a computer chip in the heater. The chip regulates the heat being generated by a large metal platen inside the heater. A LCD on the face of the heater shows the temperature of the aerosol going into the airway. The aerosol stream temperature cannot exceed 39° C or the power to the heater automatically shuts off – reducing the danger of tracheal burns.

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strongly related to the serum IgE level (p for trend < 0.0001). No asthma was reported in children with IgE levels < 32 IU per mL, whereas 36% of those with IgE levels ≥ 1000 IU per mL were reported to have asthma. This relation with the serum IgE level was not explained by a concomitant diagnosis of allergic rhinitis or eczema. Airway hyperresponsiveness to a methacholine challenge also correlated very highly ($p < 0.0001$) with the serum IgE level. This relation remained significant even after the exclusion of children with diagnosed asthma ($p < 0.0001$) and of all children with a history of wheezing, allergic rhinitis, or eczema ($p < 0.0001$). CONCLUSIONS: Even in children who have been asymptomatic throughout their lives and have no history of atopic disease, airway hyperresponsiveness appears to be closely linked to an allergic diathesis, as reflected by the serum total IgE level.

Surfactant Inactivation and Surfactant Replacement in Experimental Models of ARDS—B Robertson. Acta Anaesthesiol Scand 1991;35(Suppl 95):22.

Lung structure and function, and the effect of surfactant replacement, were studied in three animal models of adult respiratory distress syndrome (ARDS): surfactant depletion by repeated lung lavage, proteinaceous pulmonary edema induced by prolonged exposure to hyperoxia, and inoculation with hybridoma making an antibody to the hydrophobic surfactant-associated protein, SP-B. Surfactant replacement therapy restored normal gas exchange in respiratory failure induced by repeated lung lavage but was ineffective in animals with severe lung parenchymal lesions induced by hyperoxia or antibody to SP-B. Lung edema fluid from animals exposed to hyperoxia inhibited surfactant function in a concentration-dependent manner. These observations indicate that, in experimental ARDS, the effect of surfactant replacement depends on the type of animal model and, especially, on the degree of lung injury present at the time of therapy.

The Effect of Nasotracheal Intubation on the Paranasal Sinuses: A Prospective Study of 434 Intensive Care Patients—J Pedersen, BA Schurizek, NC Melsen, B Juhl. Acta Anaesthesiol Scand 1991;35:11.

A total of 434 patients admitted to the intensive care unit for mechanical ventilation were followed prospectively to investigate the influence of a nasotracheal tube on the paranasal sinuses. Twenty-five patients died before the examination was completed. The rest were examined for clinical symptoms of sinusitis. If sinusitis was suspected or the patients were intubated for 5 days or more, an x-ray of the sinuses was performed. In patients intubated for less than 5 days (n = 357), sinusitis was clinically suspected in three, but radiographically verified in only one. In patients intubated for 5 days or more (n = 47), 23 (49%) had affection of the paranasal sinuses. Patients needing a nasotracheal tube should be examined for sinusitis if they are intubated for more than 5 days or if unexplained fever, sepsis or purulent nasal secretion develops. If the suspicion is confirmed, the nasotracheal tube should be removed.

The "Educated Hand"—Can Anesthesiologists Assess Changes in Neonatal Pulmonary Compliance Manually?—RS Spears, A Yeh, DM Fisher, MS Zwass. Anes 1991;75:693.

To determine whether anesthesiologists can manually detect significant changes in pulmonary compliance in neonates using an "educated hand," the authors tested whether clinicians could detect clamping of an endotracheal tube connecting a neonatal lung model to one of three anesthesia breathing circuits. The test lungs corresponded to the lung of a full-term neonate (large lung) or a premature neonate (small lung), and the circuits were a disposable Mapleson D and a disposable pediatric circle system with and without a humidifier. Clinicians having four levels of expertise (inexperienced anesthesia residents, experienced anesthesia residents, faculty not specializing in pediatric anesthesia, and specialized pediatric anesthesia faculty) were permitted to choose fresh gas flows, ventilatory pattern, and rate. After an acclimation period, the endotracheal tube connecting the test lung to the circuit was occluded once for 30 s. Clinicians were credited with a successful detection if they reported the occlusion within 15 s and had fewer than one false positive per minute. With the large lung model, only 4 of 24 clinicians detected occlusion with the Mapleson D circuit; similar results were obtained with the other circuits. With the small lung model, the only successful detection occurred with the Mapleson D circuit. Success at detecting occlusion was similarly low for clinicians with different levels of expertise. The authors conclude that the commonly held belief that the "educated hand" permits clinicians to detect subtle changes in pulmonary compliance in neonates during anesthesia (necessi-tating manual rather than mechanical ventilation) is not true.

Contractile Properties of the Human Diaphragm during Chronic Hyperinflation—T Similowski, S Yan, AP Gauthier, PT Macklem, F Bellemare. N Engl J Med 1991; 325:917.

BACKGROUND: In patients with chronic obstructive pulmonary dis-

More hope for infants with RDS*
More proof of effectiveness
More experience
Baby's Breath
Gypsophila paniculata
®

The proven efficacy and impressive safety profile of the first protein-free, synthetic lung surfactant

Exosurf® NEONATAL™
(Colfosceril Palmitate, Cetyl Alcohol, Tyloxapol) For Intratracheal Suspension/10-mL vial

Controlled clinical trials with EXOSURF Neonatal showed "dramatic reductions" in morbidity and mortality of infants with RDS. Subsequent use under a year-long Treatment IND confirmed its efficacy and impressive safety profile. Since release for marketing in August 1990, widespread use in hospitals across the United States has further established its value in the treatment of RDS. The weight of clinical experience is in favor of EXOSURF Neonatal.

Dramatic reductions in neonatal morbidity and mortality reported in clinical trials[1-5]

Improvement in clinical outcome after EXOSURF Neonatal has been significant in infants at risk of developing RDS as well as those with established RDS. Prophylactic as well as rescue treatment with EXOSURF Neonatal has dramatically reduced morbidity and mortality in infants weighing greater than 700 grams.

SIGNIFICANT REDUCTIONS IN OVERALL MORTALITY FROM ANY CAUSE IN MIDDLE-SIZE AND LARGE INFANTS[2-5]
(Percent reductions with EXOSURF)

	Prophylactic treatment		Rescue treatment	
Age	*Single Dose*[2] 700-1100 grams (N=446)	*One vs Three Doses*[3] 700-1100 grams (N=716)	*Two Dose*[4] 700-1350 grams (N=419)	*Two Dose*[5] 1250 grams and above (N=1232)
≤10 Days	—	—	59%[§]	35%
≤28 Days	40%*	44%[‡]	52%[§]	39%
≤1 Year	44%[†]	41%[‡]	46%[§]	31%

*P=0.022. †P=0.002. ‡P<0.05. §P<0.001 ¶P=0.039. N=Number of infants enrolled in the clinical trials

A single prophylactic dose of EXOSURF Neonatal reduced 1-year mortality by 44%. Two additional prophylactic doses provided an additional 41% reduction in 1-year mortality.[3]

SIGNIFICANT REDUCTIONS IN MORTALITY FROM RDS IN MIDDLE-SIZE AND LARGE INFANTS[2,4,5]
(Percent reductions with EXOSURF)

	Prophylactic treatment	Rescue treatment	
	Single Dose[2] 700-1100 grams (N=446)	*Two Dose*[4] 700-1350 grams (N=419)	*Two Dose*[5] 1250 grams and above (N=1232)
Reduction in death from RDS	58%*	66%†	63%‡

*P=0.011 †P=0.007 ‡P=0.009. N=Number of infants enrolled in the clinical trials

SIGNIFICANT REDUCTION IN CARDIOPULMONARY DESTRUCTION TO DAY 28 FOLLOWING TWO-DOSE RESCUE TREATMENT[4,5]

(Percent reductions with EXOSURF)

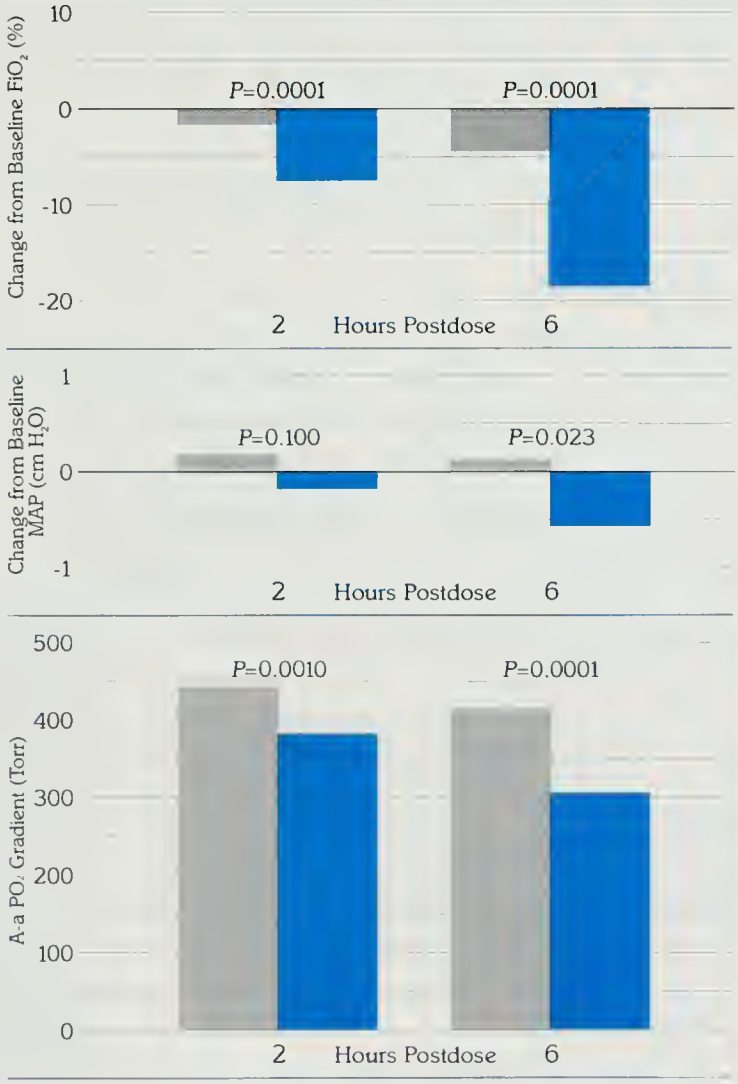
Birth weight	Reduction in death at 28 days or survival with broncho-pulmonary dysplasia (BPD)
700-1350[4] (N=419)	34%*
1250 and above[5] (N=1232)	43%*

*P=0.002. N=Number of infants enrolled in the clinical trials.

Rapid onset of action documented in rescue use[4]

Improvements in mean FiO_2 and mean alveolar-arterial PO_2 (A-a) gradient were present by 2 hours after dosing in middle-size babies (700-1350 grams). Improvements in mean airway pressures began sometime between 2 and 6 hours in middle-size babies. These improvements persisted for at least 7 days.

SIGNIFICANT IMPROVEMENTS IN SUPPLEMENTAL OXYGEN NEEDS AND VENTILATORY REQUIREMENTS SEEN IN MIDDLE-SIZE BABIES[4]



All charts from Long[4]

Please see brief summary of full prescribing information on last pages of this advertisement.

Efficacy and impressive safety profile of EXOSURF® Neonatal™ confirmed in continued widespread use[6]

In North American controlled clinical trials, more than 2600 premature infants received EXOSURF Neonatal. Under the year-long Treatment IND, over 11,400 infants received EXOSURF Neonatal. In the six months following its release for marketing, EXOSURF Neonatal has been given to 10,000 infants in more than 750 hospitals.

There are no known infectious or immunologic risks associated with EXOSURF Neonatal use. In controlled clinical trials, adverse events were comparable to those of placebo, with the exception of apnea and pulmonary bleeding. Infants receiving EXOSURF Neonatal required less ventilatory support, possibly contributing to an increased incidence of apnea. Pulmonary bleeding occurred in 1% of control infants and 2% of treated infants in controlled trials. In the treatment IND, pulmonary bleeding was reported in 4% and mucous plugging at a rate of 3/1000. Pulmonary bleeding appears to be preventable with early diagnosis and appropriate treatment of patent ductus arteriosus.

One-year follow-up evaluated developmental outcomes[7]

Double-blind 1-year follow-up of more than 1450 infants enrolled in randomized trials showed that mental and motor scores appeared to be higher in tiny infants (<750 grams) as well as middle-size infants (750-1249 grams) who received Exosurf Neonatal.

Economic data analysis showed cost savings[8-10]

Three separate studies evaluated the economic impact of a single prophylactic dose of EXOSURF Neonatal, two-dose rescue treatment in 700- to 1350-gram infants, and two-dose rescue treatment during the neonatal period in infants weighing over 1350 grams. Results indicate that both prophylactic treatment and rescue treatment are cost-effective. Mean hospital charges were $6451 less for large infants receiving two-dose rescue treatment versus air in the first 28 days of life.[10]

As easy to use as it is effective

- **Easy to store and use** EXOSURF Neonatal may be stored at room temperature. Reconstituted suspension may be maintained refrigerated or at room temperature for up to 12 hours. Key items needed for administration are supplied in one kit.
- **Easy to administer** Each EXOSURF Neonatal dose is administered in two 2.5-mL/kg half-doses without interrupting mechanical ventilation.
- **Easy on infant** To assist the distribution of EXOSURF Neonatal in the lungs, the infant is simply turned from midline position to the right after the first half-dose, and from midline position to the left after the second half-dose.

References: 1. Bose C, Corbet A, Bose G, et al. Improved outcome at 28 days of age for very low birth weight infants treated with a single dose of a synthetic surfactant. *J Pediatr* 1990;117:947-953. **2.** Corbet A, Bucciarelli R, Goldman S, et al. Decreased mortality in small premature infants treated at birth with a single dose of synthetic surfactant. a multi-center controlled trial. *J Pediatr.* 1991;118:277-284 **3.** Gerdes J, Cook L, Beaumont E, Corbet A, Long W. American EXOSURF Pediatric Groups I and II. Effects of three vs. one prophylactic doses of EXOSURF Neonatal in 700- to 1100-gram neonates. *Pediatr Res.* 1991;29(no. 4, pt 2):214A. Abstract. **4.** Long W, Thompson T, Sundell H, et al. Effects of two rescue doses of a synthetic surfactant on mortality rate and survival without bronchopulmonary dysplasia in 700- to 1350-gram infants with respiratory distress syndrome. *J Pediatr.* 1991;118:595-605. **5.** U.S. and Canadian EXOSURF Pediatric Study Groups. Effects of two rescue doses of EXOSURF® Pediatric in 1232 infants ≥1250 grams. *Pediatr Res.* 1990;27(no. 4, pt 2):320A. Abstract. **6.** Data on file, Burroughs Wellcome Co.,1991. **7.** Walter D, McGuinness G, Bose C, et al. Double-blind one-year follow-up in 1450 infants randomized to EXOSURF® Neonatal or air. *Pediatr Res.* 1991;29(no. 4, pt 2):270A. Abstract. **8.** Sell M, Corbet A, Gong A, et al. Economic impact of a single prophylactic dose of EXOSURF® Neonatal in 700- to 1100-gram infants. *Pediatr Res.* 1991;29(no. 4, pt 2):265A. Abstract. **9.** Mammel M, Mullett M, Derleth D, et al. Economic impact of two rescue doses of EXOSURF® Neonatal in 700-1350 gram infants. *Pediatr Res.* 1991;29(no. 4, pt 2):260A. Abstract. **10.** Schumacher R, Burchfield D, Vaughan R, et al. Economic impact of two rescue doses of EXOSURF® Neonatal in ≥1350 gram infants. *Pediatr Res.* 1991;29(no. 4, pt 2):264A. Abstract.

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Wellcome

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EX-Y01228

EXOSURF® Neonatal™
(COLFOSCERIL PALMITATE, CETYL ALCOHOL, TYLOXAPOL)
For Intratracheal Suspension / 10 mL vials

PLEASE CONSULT FULL PRODUCT INFORMATION BEFORE PRESCRIBING

INDICATIONS AND USAGE Exosurf Neonatal is indicated for

1 **Prophylactic** treatment of infants with birth weights of less than 1350 grams who are at risk of developing RDS (see PRECAUTIONS),

2 **Prophylactic** treatment of infants with birth weights greater than 1350 grams who have evidence of pulmonary immaturity, and

3 **Rescue** treatment of infants who have developed RDS

CONTRAINDICATIONS: There are no known contraindications to treatment with Exosurf Neonatal

WARNINGS: **Intratracheal Administration Only**: Exosurf Neonatal should be administered only by instillation into the trachea **General**. The use of Exosurf Neonatal requires expert clinical care by experienced neonatologists and other clinicians who are accomplished at neonatal intubation and ventilatory management. Adequate personnel, facilities, equipment, and medications are required to optimize perinatal outcome in premature infants. Instillation of Exosurf Neonatal should be performed **only** by trained medical personnel experienced in airway and clinical management of unstable premature infants. Vigilant clinical attention should be given to all infants prior to, during, and after administration of Exosurf Neonatal. **Acute Effects**: Exosurf Neonatal can rapidly affect oxygenation and lung compliance. **Lung Compliance**. If chest expansion improves substantially after dosing, peak ventilator inspiratory pressures should be reduced immediately without waiting for confirmation of respiratory improvement by blood gas assessment. Failure to reduce inspiratory ventilator pressures rapidly in such instances can result in lung overdistention and fatal pulmonary air leak. **Hyperoxia**: If the infant becomes pink and transcutaneous oxygen saturation is in excess of 95%, FiO_2 should be reduced in small but repeated steps (until saturation is 90 to 95%) without waiting for confirmation of elevated arterial pO_2 by blood gas assessment. Failure to reduce FiO_2 in such instances can result in hyperoxia. **Hypocarbia**. If arterial or transcutaneous CO_2 measurements are <30 torr, the ventilator rate should be reduced at once. Failure to reduce ventilator rates in such instances can result in marked hypocarbia, which is known to reduce brain blood flow. **Pulmonary Hemorrhage**: In the single study conducted in infants weighing <700 grams at birth, the incidence of pulmonary hemorrhage (10% vs 2% in the placebo group) was significantly increased in the Exosurf Neonatal group. None of the five studies involving infants with birth weights >700 grams showed a significant increase in pulmonary hemorrhage in the Exosurf Neonatal group. In a cross-study analysis of these five studies, pulmonary hemorrhage was reported for 1% (14/1420) of infants in the placebo group and 2% (27/1411) of infants in the Exosurf Neonatal group. Fatal pulmonary hemorrhage occurred in three infants, two in the Exosurf Neonatal group and one in the placebo group. Mortality from all causes among infants who developed pulmonary hemorrhage was 43% in the placebo group and 37% in the Exosurf Neonatal group. Pulmonary hemorrhage in both Exosurf Neonatal and placebo infants was more frequent in infants who were younger, smaller, male, or who had a patent ductus arteriosus. Pulmonary hemorrhage typically occurred in the first 2 days of life in both treatment groups. In more than 7700 infants in the open, uncontrolled study, pulmonary hemorrhage was reported in 4%, but fatal pulmonary hemorrhage was reported rarely (0.4%). In the controlled clinical studies, Exosurf Neonatal treated infants who received steroids more than 24 hours prior to delivery or indomethacin postnatally had a lower rate of pulmonary hemorrhage than other Exosurf Neonatal treated infants. Attention should be paid to early and aggressive diagnosis and treatment (unless contraindicated) of patent ductus arteriosus during the first 2 days of life (while the ductus arteriosus is often clinically silent). Other potentially protective measures include attempting to decrease FiO_2 preferentially over ventilator pressures during the first 24 to 48 hours after dosing, and attempting to decrease PEEP minimally for at least 48 hours after dosing. **Mucous Plugs**: Infants whose ventilation becomes markedly impaired during or shortly after dosing may have mucous plugging of the endotracheal tube, particularly if pulmonary secretions were prominent prior to drug administration. Suctioning of all infants prior to dosing may lessen the chance of mucous plugs obstructing the endotracheal tube. If endotracheal tube obstruction from such plugs is suspected, and suctioning is unsuccessful in removing the obstruction, the blocked endotracheal tube should be replaced immediately

PRECAUTIONS:
General: In the controlled clinical studies, infants known prenatally or postnatally to have major congenital anomalies or who were suspected of having congenital infection, were excluded from entry. However, these disorders cannot be recognized early in life in all cases, and a few infants with these conditions were entered. The benefits of Exosurf Neonatal in the affected infants who received drug appeared to be similar to the benefits observed in infants without anomalies or occult infection. **Prophylactic Treatment–Infants <700 Grams**: In infants weighing 500 to 700 grams, a single prophylactic dose of Exosurf Neonatal significantly improved FiO_2 and ventilator settings, reduced pneumothorax, and reduced death from RDS, but increased pulmonary hemorrhage (see WARNINGS). Overall mortality did not differ significantly between the placebo and Exosurf Neonatal groups (see Table 1 in full product information). Data on multiple doses in infants in this weight class are not yet available. Accordingly, clinicians should carefully evaluate the potential risks and benefits of Exosurf Neonatal administration in these infants. **Rescue Treatment–Number of Doses**: A small number of infants with RDS have received more than two doses of Exosurf Neonatal as rescue treatment. Definitive data on the safety and efficacy of these additional doses are not available. **Carcinogenesis, Mutagenesis, Impairment of Fertility**: Exosurf Neonatal at concentrations up to 10,000 µg/plate was not mutagenic in the Ames Salmonella assay. Long-term studies have not been performed in animals to evaluate the carcinogenic potential of Exosurf Neonatal. The effects of Exosurf Neonatal on fertility have not been studied

ADVERSE REACTIONS:
General: Premature birth is associated with a high incidence of morbidity and mortality. Despite significant reductions in overall mortality associated with Exosurf Neonatal, some infants who received Exosurf Neonatal developed severe complications and either survived with permanent handicaps or died.

In controlled clinical studies evaluating the safety and efficacy of Exosurf Neonatal, numerous safety assessments were made. In infants receiving Exosurf Neonatal, pulmonary hemorrhage, apnea and use of methylxanthines were increased. A number of other adverse events were significantly reduced in the Exosurf Neonatal group, particularly various forms of pulmonary air leak and use of pancuronium. Tables 3 and 4 summarize the results of the major safety evaluations from the controlled clinical studies.

Table 3 Safety Assessments[a]—Prophylactic Treatment

Number of Doses / Birth Weight Range	Single Dose 500 to 700 grams		Single Dose 700 to 1350 grams		Single Dose 700 to 1100 grams		1 vs 3 Doses 700 to 1100 grams	
Treatment Group / Number of Infants	Placebo (Air) N=108	EXOSURF N=107	Placebo (Air) N=193	EXOSURF N=192	Placebo (Air) N=222	EXOSURF N=224	EXOSURF 1 Dose N=356	EXOSURF 3 Doses N=360
	% of Infants		% of Infants		% of Infants		% of Infants	
Intraventricular Hemorrhage (IVH)								
Overall	51	57	31	27	36	36	38	35
Severe IVH	26	25	10	8	13	14	9	9
Pulmonary Air Leak (PAL)								
Overall	52	48	16	11	32	25	29	27
Pneumothorax	23	10*	5	6	19	11*	14	12
Pneumopericardium	1	4	2	0	<1	1	1	1
Pneumomediastinum	2	1	2	3	7	1**	3	2
Pulmonary Interstitial Emphysema	43	44	13	7*	26	20	23	22
Death from PAL	4	6	<1	<1	2	1	2	1
Patent Ductus Arteriosus	49	53	66	70	50	55	59	57
Necrotizing Enterocolitis	2	4	11	13	3	4	6	2*
Pulmonary Hemorrhage	2	10**	2	4	1	4	4	6
Congenital Pneumonia	4	4	2	4	2	2	1	1
Nosocomial Pneumonia	10	10	2	4	4	7	14	15
Non-Pulmonary Infections	33	35	34	39	28	29	35	34
Sepsis	30	34	30	34	23	24	30	27
Death From Sepsis	4	4	3	3	1	2	3	2
Meningitis	4	6	3	1	2	3	1	2
Other Infections	7	4	5	3	6	10	10	11
Major Anomalies	3	1	2	4	7	4	4	4
Hypotension	70	77	52	47	59	62	54	50
Hyperbilirubinemia	22	21	63	61	27	31	20	21
Exchange Transfusion	4	3	1	2	2	2	3	1
Thrombocytopenia[b]	21	25	not available		9	8	12	10
Persistent Fetal Circulation	0	1	1	1	0	2*	1	<1
Seizures	11	8	2	2	11	9	6	5
Apnea	34	33	76	73	55	65*	62	68
Drug Therapy								
Antibiotics	96	99	98	96	98	99	>99	99
Diuretics	55	60	39	37	59	63	64	65
Anticonvulsants	14	18	23	24	20	16	9	8
Inotropes	46	40	20	20	26	20	28	27
Sedatives	62	71	65	64	63	57	52	52
Pancuronium	19	11	22	14*	19	13*	15	11
Methylxanthines	38	43	77	77	61	72*	75	82*

[a] All parameters were examined with "as-treated" analyses. * p<0.05. ** p<0.01.
[b] Thrombocytopenia requiring platelet transfusion

Table 4 Safety Assessments[a]—Rescue Treatment

Number of Doses / Birth Weight Range	Two Doses 700 to 1350 grams		Two Doses 1250 grams and above	
Treatment Group / Number of Infants	Placebo (Air) N=213	EXOSURF N=206	Placebo (Air) N=622	EXOSURF N=615
	% of Infants		% of Infants	
Intraventricular Hemorrhage (IVH)				
Overall	48	52	23	18*
Severe IVH	13	9	5	4
Pulmonary Air Leak (PAL)				
Overall	54	34***	30	18***
Pneumothorax	29	20*	20	10***
Pneumopericardium	4	1	1	2
Pneumomediastinum	8	4	5	2**
Pulmonary Interstitial Emphysema	48	25***	24	13***
Death from PAL	7	3	<1	1
Patent Ductus Arteriosus	66	57	54	45*
Necrotizing Enterocolitis	3	3	1	2
Pulmonary Hemorrhage	3	1	<1	1
Congenital Pneumonia	2	3	2	2
Nosocomial Pneumonia	5	7	2	2
Non-Pulmonary Infections	19	22	13	13
Sepsis	15	17	8	8
Death From Sepsis	<1	<1	1	<1
Meningitis	1	<1	1	<1*
Other Infections	5	8	5	6
Major Anomalies	3	3	4	4
Hypotension	62	57	50	39**
Hyperbilirubinemia	17	19	12	10
Exchange Transfusion	3	4	1	2
Thrombocytopenia[b]	10	11	4	<1**
Persistent Fetal Circulation	1	1	6	2**
Seizures	10	10	6	3*
Apnea	48	65**	37	44*
Drug Therapy				
Antibiotics	100	99	98	98
Diuretics	60	65	45	34***
Anticonvulsants	17	17	10	5**
Inotropes	36	31	27	16***
Sedatives	72	68	76	64***
Pancuronium	34	17**	33	15***
Methylxanthines	62	74**	49	53

[a] All parameters were examined with "as-treated" analyses. * p<0.05. ** p<0.01. *** p<0.001.
[b] Thrombocytopenia requiring platelet transfusion

Pulmonary Hemorrhage See WARNINGS. **Abnormal Laboratory Values**: Abnormal laboratory values are common in critically ill, mechanically ventilated premature infants. A higher incidence of abnormal laboratory values in the Exosurf Neonatal group was not reported. **Events During Dosing**: Data on events during dosing are available from more than 8800 infants in the open, uncontrolled clinical study (Table 5).

Table 5 Events During Dosing in the Open, Uncontrolled Study[a]

Treatment Type / Number of Infants	Prophylactic Treatment N=1127	Rescue Treatment N=7711
	% of Infants	% of Infants
Reflux of Exosurf	20	31
Drop in O_2 saturation (≥ 20%)	6	22
Rise in O_2 saturation (≥ 10%)	5	6
Drop in transcutaneous pO_2 (≥ 20 mm Hg)	1	8
Rise in transcutaneous pO_2 (≥ 20 mm Hg)	2	5
Drop in transcutaneous pCO_2 (≥ 20 mm Hg)	<1	1
Rise in transcutaneous pCO_2 (≥ 20 mm Hg)	1	3
Bradycardia (<60 beats/min)	1	3
Tachycardia (>200 beats/min)	<1	<1
Gagging	1	5
Mucous Plugs	<1	<1

[a] Infants may have experienced more than one event.
Investigators were prohibited from adjusting FiO_2 and/or ventilator settings during dosing unless significant clinical deterioration occurred.

Reflux: Reflux of Exosurf Neonatal into the endotracheal tube during dosing has been observed and may be associated with rapid drug administration. If reflux occurs, drug administration should be halted and, if necessary, peak inspiratory pressure on the ventilator should be increased by 4 to 5 cm H_2O until the endotracheal tube clears. ***>20% Drop in Transcutaneous Oxygen Saturation***: If transcutaneous oxygen saturation declines during dosing, drug administration should be halted and, if necessary, peak inspiratory pressure on the ventilator should be increased by 4 to 5 cm H_2O for 1 to 2 minutes. In addition, increases of FiO_2 may be required for 1 to 2 minutes. ***Mucous Plugs***: See WARNINGS.

DOSAGE AND ADMINISTRATION See full product information.

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ease (COPD) and hyperinflation of the lungs, dysfunction of the diaphragm may contribute to respiratory decompensation. We evaluated the contractile function of the diaphragm in well-nourished patients with stable COPD, using supramaximal, bilateral phrenic-nerve stimulation, which provides information about the strength and inspiratory action of the diaphragm. METHODS: In eight patients with COPD and five control subjects of similar age, the transdiaphragmatic pressure generated by the twitch response to phrenic-nerve stimulation was recorded at various base-line lung volumes, from functional residual capacity to total lung capacity, and during relaxation and graded voluntary efforts at functional residual capacity (twitch occlusion). RESULTS: At functional residual capacity, the twitch transdiaphragmatic pressure ranged from 10.9 to 26.6 cm of water [1.07 to 2.60 kPa] in the patients and from 19.8 to 37.1 cm of H_2O [1.94 to 3.64 kPa] in the controls, indicating considerable overlap between the two groups. The ratio of esophageal pressure to twitch transdiaphragmatic pressure, an index of the inspiratory action of the diaphragm, was –0.50 ± 0.05 in the patients, as compared with –0.43 ± 0.02 in the controls (indicating more efficient inspiratory action in the patients than in the controls). At comparable volumes, the twitch transdiaphragmatic pressure and esophageal-to-transdiaphragmatic pressure ratio were higher in the patients than in normal subjects, indicating that the strength and inspiratory action of the diaphragm in the patients were actually better than in the controls. Twitch occlusion (a measure of the maximal activation of the diaphragm) indicated near-maximal activation in the patients with COPD, and the maximal transdiaphragmatic pressure was 106.9 ± 13.8 cm of H_2O [10.48 ± 1.35 kPa]. CONCLUSIONS: The functioning of the diaphragms of the patients with stable COPD is as good as in normal subjects at the same lung volume. Compensatory phenomena appear to counterbalance the deleterious effects of hyperinflation on the contractility and inspiratory action of the diaphragm in patients with COPD. Our findings cast doubt on the existence of chronic fatigue of the diaphragm in such patients and therefore on the need for therapeutic interventions aimed at improving diaphragm function.

Hyperventilation Reduces Transcutaneous Oxygen Tension and Skin Blood Flow—SJ Barker, J Hyatt, C Clarke, KK Tremper. Anesthesiology 1991;75:619.

Transcutaneous oxygen tension ($P_{tc}CO_2$) is often used to monitor neonates and infants in special care units and the operating room. The transcutaneous index (TCI = $P_{tc}CO_2$/ arter-ial oxygen tension [P_aO_2]) is known to depend both on age and on cardiac index but is assumed to be independent of other physiologic variables. In this study we have shown that TCI also depends upon arterial carbon dioxide tension (P_aCO_2). Five young pigs were anesthetized and paralyzed and their lungs mechanically ventilated while they were monitored with $P_{tc}CO_2$ electrodes and serial arterial blood gas analyses. For a 45°C $P_{tc}CO_2$ sensor, the mean TCI during normocapnia was 0.78, whereas during hyperventilation (P_aCO_2 = 20 torr) the mean TCI was reduced 65%, to 0.27. The corresponding TCI values for a 43°C sensor were 0.33 and 0.065, representing an 80% decrease in TCI during hyperventilation. Hypoventila-tion had little effect upon TCI as long as hypoxemia was avoided. Twelve awake adult volunteers with radial artery cannulas were moni-tored with $P_{tc}CO_2$ sensors at several body sites and two sensor temperatures. For a 44°C sensor on the chest, the mean TCI decreased from 0.77 at normocapnia to 0.60 at a P_aCO_2 of 17 torr, a 22% change. For the same sensor on the foot, TCI decreased from 0.63 to 0.32, a 49% change. For a 42°C sensor under the same conditions, the corresponding TCI decreases were 51 and 64%. Six of the volunteers were also monitored with laser-Doppler skin blood flow probes located on the chest, hand, and foot. The skin blood flow measured on the chest decreased by an average of 8% during hyperventilation; blood flow on the hand (thenar eminence) decreased by 60%; and blood flow on the foot decreased by 51%. The TCI is significantly reduced in both swine and adult humans during hyperventilation. This effect is greater on the extremities and at lower sensor temperatures. Laser-Doppler velocimetry measurements indicate a corresponding reduction in cutaneous blood flow during hyperventilation. Transcutaneous oxygen should be used with caution as a predictor of P_aO_2 during spontaneous or controlled hyperventilation.

Thoracoscopic Carbon Dioxide Laser Treatment of Bullous Emphysema—A Wakabayashi, M Brenner, RA Kayaleh, MW Berns, SJ Barker, SJ Rice, et al. Lancet 1991;337:881.

A new technique of thoracoscopic laser ablation of pulmonary bullae suitable for patients with multiple bullae and diffuse emphysema was developed and assessed in 22 patients. Twenty of 22 patients survived. Preoperative and postoperative functional evaluation is available for the 11 patients followed up for more than a month; at 1 to 3 months postoperatively there were increases in forced vital capacity (FVC) (mean 2.0 L preoperatively to 2.7 L postoperatively, $p < 0.001$), in

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FEV_1 (0.74 to 1.06 L, $p = 0.01$), and in maximum exercise treadmill times (5.4 to 8.0 min, $p < 0.01$). Postoperative air leaks lasted a mean of 13 days and usually resolved spontaneously. Other complications were bleeding (1 patient) and unilateral acute lung injury (1 patient). These early results suggest that selected patients with diffuse emphysema and pulmonary bullae may benefit from thoracoscopic carbon dioxide laser ablation.

Ductal Patency in Neonates with Respiratory Distress Syndrome—MD Reller, DC Buffkin, MA Colasurdo, MJ Rice, RW McDonald. AJDC 1991;145:1017.

The purpose of this study was to evaluate in a controlled study the effect of exogenous surfactant on various manifestations of ductal patency. Premature infants with respiratory distress syndrome were randomized to receive surfactant (Survanta) (n = 22) or air (n = 14). In neonates receiving surfactant, there was a greater tendency for an audible murmur to develop (13 of 22 vs 4 of 14). Inspite of this, the clinical use of indomethacin was similar for the two groups, 10 (45%) of 2 vs 6 (43%) of 14. Excluding neonates given indomethacin early, comparable number of surfactant-treated neonates (9/17 [53%]) vs control neonates (6/12 [50%]) demonstrated spontaneous closure of the ductus within a physiologic time frame (on or before Day 4). For the gestational ages studied, the beneficial effects of exogenous surfactant were not associated with either an increased risk for delayed closure of the ductus arteriosus or a greater incidence of indomethacin usage. Utilization of exogenous surfactant does not appear to have an adverse impact on ductal patency.

Optimal Positioning of Endotracheal Tubes for Ventilation of Preterm Infants—A Rotschild, D Chitayat, ML Puterman, MS Phang, E Ling, V Baldwin. AJDC 1991; 145:1007.

Accurate knowledge of upper-airway dimensions is required to prevent mal-positioning of endotracheal tubes in preterm infants. We measured vocal cord-carina, oral-carina, nasal-carina distances in situ at autopsy of two groups of infants (< 1,000 and ≥ 1,000 g). In all 24 infants, crown-heel length, crown-rump length, and occipitofrontal circumference were better than weight in predicting upper-airway dimensions. Flexion of the neck decreased and extension increased both nasal-carina and oral-carina distances. Lateral rotation produced no significant changes. The postmortem data were not different from nasal-carina distances measured radiologically in 40 living, nasally intubated and ventilated infants, confirming the clinical validity of our findings. Regression equations were derived to predict optimal endotracheal tube lengths based on the external measurements of crown-rump length and crown-heel length.

Impairments, Disabilities, and Handicaps of Very Preterm and Very-Low-Birthweight Infants at Five Years of Age—S Veen, MH Ens-Dokkum, AM Schreuder, SP Verloove-Vanhorick, R Brand, JH Ruys. Lancet 1991;338:33.

The Project on Preterm and Small for gestational age infants (POPS) was started in the Netherlands in 1983 to investigate the relation between prenatal/perinatal factors and mortality/morbidity in very preterm and very-low-birthweight infants. Of the 1,338 liveborn infants (< 32 weeks and/or 1,500 g), 966 were enrolled in the 5-year (chronological age) follow-up programme; 96% of these children were assessed during a home visit. The overall outcome was expressed as impairments, disabilities, and handicaps according to World Health Organisation criteria. Of the assessed children, 13% had a disability and 14% were handicapped, which are much higher frequencies than those found in the general population. Handicaps were due mainly to abnormalities of neuromotor function, mental development, or language and speech development. Compared with the handicap frequency in the same cohort at 2 years of age, a more favourable outcome at 5 years of age was seen in 10%, and a less favourable outcome in 7% of the children. The findings show that most of those high-risk children survived without handicap or serious disability at preschool age.

Effects of Positive End-Expiratory Pressure, Lung Volume, and Inspiratory Flow on Interrupter Resistance in Patients with Adult Respiratory Distress Syndrome—NT Eissa, VM Ranieri, C Corbeil, M Chasse, J Braidy, J Milic-Emili. Am Rev Respir Dis 1991;144:538.

Although it has been shown in normal subjects that airway resistance changes significantly with changes in lung volume and inspiratory flow, no studies have as yet examined these phenomena in patients with adult respiratory distress syndrome (ARDS). The effect of positive end-expiratory pressure (PEEP) on airway resistance in ARDS also is unknown. We have used the technique of rapid airway occlusion during constant-flow inflation to measure the interrupter resistance ($R_{int,rs}$), which in humans is thought to correspond to airway resistance, in 9 patients with ARDS under different inflation flows and volumes. This procedure was carried out at four levels of PEEP (0, 5, 10, and 15 cm H_2O). We found that (1) at constant inflation volume, $R_{int,rs}$ did not change significantly with

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INDICATIONS AND USAGE

SURVANTA is indicated for prevention and treatment ("rescue") of Respiratory Distress Syndrome (RDS) (hyaline membrane disease) in premature infants. SURVANTA significantly reduces the incidence of RDS, mortality due to RDS and air leak complications.

Prevention

In premature infants less than 1250 g birth weight or with evidence of surfactant deficiency, give SURVANTA as soon as possible, preferably within 15 minutes of birth.

Rescue

To treat infants with RDS confirmed by x-ray and requiring mechanical ventilation, give SURVANTA as soon as possible, preferably by 8 hours of age.

CONTRAINDICATIONS

None known.

WARNINGS

SURVANTA is intended for intratracheal use only.

SURVANTA CAN RAPIDLY AFFECT OXYGENATION AND LUNG COMPLIANCE. Therefore, its use should be restricted to a highly supervised clinical setting with immediate availability of clinicians experienced with intubation, ventilator management, and general care of premature infants. Infants receiving SURVANTA should be frequently monitored with arterial or transcutaneous measurement of systemic oxygen and carbon dioxide.

DURING THE DOSING PROCEDURE, TRANSIENT EPISODES OF BRADYCARDIA AND DECREASED OXYGEN SATURATION HAVE BEEN REPORTED. If these occur, stop the dosing procedure and initiate appropriate measures to alleviate the condition. After stabilization, resume the dosing procedure.

PRECAUTIONS

General

Rales and moist breath sounds can occur transiently after administration. Endotracheal suctioning or other remedial action is not necessary unless clear-cut signs of airway obstruction are present.

Increased probability of post-treatment nosocomial sepsis in SURVANTA-treated infants was observed in the controlled clinical trials (Table 3). The increased risk for sepsis among SURVANTA-treated infants was not associated with increased mortality among these infants. The causative organisms were similar in treated and control infants. There was no significant difference between groups in the rate of post-treatment infections other than sepsis.

Use of SURVANTA in infants less than 600 g birth weight or greater than 1750 g birth weight has not been evaluated in controlled trials. There is no controlled experience with use of SURVANTA in conjunction with experimental therapies for RDS (eg, high-frequency ventilation or extracorporeal membrane oxygenation).

No information is available on the effects of doses other than 100 mg phospholipids/kg, more than four doses, dosing more frequently than every 6 hours, or administration after 48 hours of age.

Carcinogenesis, Mutagenesis, Impairment of Fertility

Reproduction studies in animals have not been completed. Mutagenicity studies were negative. Carcinogenicity studies have not been performed with SURVANTA.

ADVERSE REACTIONS

The most commonly reported adverse experiences were associated with the dosing procedure. In the multiple-dose controlled clinical trials, transient bradycardia occurred with 11.9% of doses. Oxygen desaturation occurred with 9.8% of doses.

Other reactions during the dosing procedure occurred with fewer than 1% of doses and included endotracheal tube reflux, pallor, vasoconstriction, hypotension, endotracheal tube blockage, hypertension, hypocarbia, hypercarbia, and apnea. No deaths occurred during the dosing procedure, and all reactions resolved with symptomatic treatment.

The occurrence of concurrent illnesses common in premature infants was evaluated in the controlled trials. The rates in all controlled studies are in Table 3.

TABLE 3

	All Controlled Studies		
Concurrent Event	SURVANTA (%)	Control (%)	P-Value[a]
Patent ductus arteriosus	46.9	47.1	0.814
Intracranial hemorrhage	48.1	45.2	0.241
Severe intracranial hemorrhage	24.1	23.3	0.693
Pulmonary air leaks	10.9	24.7	<0.001
Pulmonary interstitial emphysema	20.2	38.4	<0.001
Necrotizing enterocolitis	6.1	5.3	0.427
Apnea	65.4	59.6	0.283
Severe apnea	46.1	42.5	0.114
Post-treatment sepsis	20.7	16.1	0.019
Post-treatment infection	10.2	9.1	0.345
Pulmonary hemorrhage	7.2	5.3	0.166

[a]P-value comparing groups in controlled studies

When all controlled studies were pooled, there was no difference in intracranial hemorrhage. However, in one of the single-dose rescue studies and one of the multiple-dose prevention studies, the rate of intracranial hemorrhage was significantly higher in SURVANTA patients than control patients (63.3% *v* 30.8%, $P=0.001$, and 48.8% *v* 34.2%, $P=0.047$, respectively). The rate in a Treatment IND involving approximately 4400 infants was lower than in the controlled trials.

In the controlled clinical trials, there was no effect of SURVANTA on results of common laboratory tests: white blood cell count and serum sodium, potassium, bilirubin, creatinine.

More than 3700 pretreatment and post-treatment serum samples were tested by Western Blot immunoassay for antibodies to surfactant-associated proteins SP-B and SP-C. No IgG or IgM antibodies were detected.

Several other complications are known to occur in premature infants. The following conditions were reported in the controlled clinical studies. The rates of the complications were not different in treated and control infants, and none of the complications were attributed to SURVANTA.

Respiratory: lung consolidation, blood from the endotracheal tube, deterioration after weaning, respiratory decompensation, subglottic stenosis, paralyzed diaphragm, respiratory failure

Cardiovascular: hypotension, hypertension, tachycardia, ventricular tachycardia, aortic thrombosis, cardiac failure, cardiorespiratory arrest, increased apical pulse, persistent fetal circulation, air embolism, total anomalous pulmonary venous return

Gastrointestinal: abdominal distention, hemorrhage, intestinal perforations, volvulus, bowel infarct, feeding intolerance, hepatic failure, stress ulcer

Renal: renal failure, hematuria

Hematologic: coagulopathy, thrombocytopenia, disseminated intravascular coagulation

Central Nervous System: seizures

Endocrine/Metabolic: adrenal hemorrhage, inappropriate ADH secretion, hyperphosphatemia

Musculoskeletal: inguinal hernia

Systemic: fever, deterioration

Follow-Up Evaluations

To date, no long-term complications or sequelae of SURVANTA therapy have been found.

Single-Dose Studies

Six-month adjusted-age follow-up evaluations of 232 infants (115 treated) demonstrated no clinically important differences between treatment groups in pulmonary and neurologic sequelae, incidence or severity of retinopathy of prematurity, rehospitalizations, growth, or allergic manifestations.

Multiple-Dose Studies

Six-month adjusted age follow-up evaluations have not been completed. Preliminarily, in 605 (333 treated) of 916 surviving infants, there are trends for decreased cerebral palsy and need for supplemental oxygen in SURVANTA infants. Wheezing at the time of examination tended to be more frequent among SURVANTA infants, although there was no difference in bronchodilator therapy.

Twelve-month follow-up data from the multiple-dose studies have been completed in 328 (171 treated) of 909 surviving infants. To date no significant differences between treatments have been found, although there is a trend toward less wheezing in SURVANTA infants in contrast to the six month results.

OVERDOSAGE

Overdosage with SURVANTA has not been reported. Based on animal data, overdosage might result in acute airway obstruction. Treatment should be symptomatic and supportive.

Rales and moist breath sounds can transiently occur after SURVANTA is given, and do not indicate overdosage. Endotracheal suctioning or other remedial action is not required unless clear-cut signs of airway obstruction are present.

HOW SUPPLIED

SURVANTA (beractant) Intratracheal Suspension is supplied in single-use glass vials containing 8 mL of SURVANTA (NDC 0074-1040-08). Each milliliter contains 25 mg of phospholipids (200 mg phospholipids/8 mL) suspended in 0.9% sodium chloride solution. The color is off-white to light brown.

Store unopened vials at refrigeration temperature (2-8°C). Protect from light. Store vials in carton until ready for use. Vials are for single use only. Upon opening, discard unused drug.

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increasing flow; (2) at constant inflation flow, Rint,rs showed an initial decrease followed by a distinct rise with increasing lung volume; (3) on average, PEEP did not significantly change Rint,rs measured during baseline ventilation; and (4) this latter finding occurred because patients behaved differently with application of PEEP, depending on their degree of lung inflation: Rint,rs measured close to full inflation almost invariably exhibited a rise, but values obtained at lower volumes exhibited the characteristic decrease of Rint,rs with increasing inflation volume.

Perfusion of the Interventricular Septum during Ventilation with Positive End-Expiratory Pressure—B Zwissler, R Schosser, C Schwickert, P Spengler, M Weiss, V Iber, et al. Crit Care Med 1991; 19:1414.

OBJECTIVE: To determine whether regional hypoperfusion of the interventricular septum occurs during ventilation with positive end-expiratory pressure. DESIGN: Animal study. ANIMALS: Anesthetized, closed chest dogs (n = 8). INTERVENTIONS: Induction of experimental adult respiratory distress syndrome (ARDS) and then ventilation with 10, 15, and 20 cm H_2O of positive end-expiratory pressure. MEASUREMENTS AND MAIN RESULTS: Cardiac output and regional interventricular septum blood flow were assessed at control, at induction of experimental ARDS, and at each level of positive end-expiratory pressure. Ventilation with 20 cm H_2O of positive end-expiratory pressure decreased cardiac output (-32% vs control, $p < 0.05$), and did not change absolute, but increased relative (to cardiac output) interventricular septum blood flow. During experimental ARDS and ventilation at 20 cm H_2O end-expiratory pressure, there was a redistribution of flow toward the right ventricular free wall (+93%, $p < 0.001$) and the right ventricular part of the interventricular septum (+68%, $p < 0.01$), while flow to the left ventricular free wall remained unchanged. Locally hypoperfused interventricular septum areas or findings indicative of interventricular septum ischemia were not observed during positive end-expiratory pressure. CONCLUSIONS: The decrease in cardiac output during positive end-expiratory pressure is not caused by impaired interventricular septum blood supply. The preferential perfusion of the right ventricular interventricular septum indicates increased local right ventricular interventricular septum oxygen-demand and suggests that during positive end-expiratory pressure, this part of the interventricular septum functionally dissociates from the left ventricular interventricular septum and the left ventricular free wall to support the stressed right ventricle.

Comparison of Oxygen Consumption Measurements: Indirect Calorimetry versus the Reversed Fick Method—MN Smithies, B Royston, K Makita, K Konieczko, JF Nunn. Crit Care Med 1991;19:1401.

OBJECTIVE: To compare measurement of oxygen consumption ($\dot{V}O_2$) by spirometry and the reversed Fick method. DESIGN: Within-patient comparison using simultaneous measurements by the two methods, one previously calibrated on a metabolic simulator. PATIENTS: Twenty sets of observations on eight patients (57 to 83 yrs) requiring mechanical ventilation in a critical care unit. INTERVENTIONS: None during or immediately before the measurements. MEASUREMENTS AND MAIN RESULTS: Duplicate pairs of measurements of $\dot{V}O_2$ were made with a previously validated spirometric technique and the reversed Fick method ($Qt[CaO_2 - C_{\bar{v}}O_2]$), where Qt is cardiac output, CaO_2 is arterial oxygen content, and $C_{\bar{v}}O_2$ is mixed venous oxygen content. The coefficient of variation of the difference between duplicate measurements by the former technique was only 2.53% compared with 10.4% for the latter. The mean $\dot{V}O_2$ measurement by the spirometric method was 285.7 ± 40.7 (SD) mL/min standard temperature and pressure, dry (STPD) and for the reversed Fick method, the mean $\dot{V}O_2$ measurement was 249.3 ± 38.5 mL/min STPD ($p < 0.001$). CONCLUSIONS: The repeatability of the spirometric method was four times better than the reversed Fick method. The latter gave a significantly lower value that probably, in part, reflects the $\dot{V}O_2$ of the lung, which is included in the spirometric method but not in the reversed Fick measurement.

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Laboratory and Clinical Evaluation of the Impact Uni-Vent 750 Portable Ventilator

Robert S Campbell RRT, Kenneth Davis Jr MD, Daniel J Johnson MD, David Porembka DO, and James M Hurst MD

BACKGROUND: Transportation of critically ill, mechanically ventilated patients from intensive care units for diagnostic and therapeutic procedures has become common in the last decade. Maintenance of adequate oxygenation and ventilation during transport is essential. We evaluated the Impact Uni-Vent 750 portable ventilator in the laboratory and in the clinical arena to determine its usefulness during inhospital transport. MATERIALS & METHODS: In the laboratory, we determined the Uni-Vent 750's ability to assure tidal volume (V_T) delivery in the face of decreasing compliance of a test lung and tested the alarm systems. Using a two-compartment lung model modified to simulate spontaneous breathing, we also evaluated the responsiveness of the demand valve. The clinical evaluation was accomplished by comparing arterial blood gas values and ventilator settings in the intensive care unit before transport to those during transport. RESULTS: As lung compliance was reduced from 0.1 to 0.02 mL/cm H_2O [1.0 to 0.20 L/kPa], a slight, statistically insignificant decrease in delivered tidal volume was observed. All alarm systems operated according to manufacturer's specifications. The demand valve triggered appropriately with PEEP from 0 to 20 cm H_2O [0 to 1.96 kPa]. Sensitivity settings < –6 cm H_2O [–0.59 kPa] sometimes resulted in inability to trigger the demand valve. During patient transport, arterial blood gas values and ventilator settings were comparable to those observed in the ICU. Because an F_{IO_2} of 1.0 was used during transport, mean (SD) P_{aO_2} was significantly greater 89 (26) vs 341 (78) [11.8 (3.5) vs 45.3 (10.4) kPa]. CONCLUSIONS: The Uni-Vent 750 is a reliable transport ventilator, capable of maintaining adequate oxygenation and ventilation in a majority of mechanically ventilated patients. The Uni-Vent 750's ability to (1) provide CMV, AMV, and SIMV; (2) provide low and high pressure alarms; and (3) provide PEEP compensation is unique among portable ventilators. (Respir Care 1992;37:29-36.)

Mr Campbell is Critical Care Coordinator for Respiratory Care, Dr Davis is Associate Professor of Surgery, Dr Johnson is Assistant Professor of Surgery, Dr Porembka is Assistant Professor of Surgery and Anesthesia, and at the time this study was conducted Dr Hurst was Director, Division of Trauma/Critical Care, and Professor of Surgery and Anesthesia—University of Cincinnati Medical Center and University of Cincinnati College of Medicine, Cincinnati, Ohio. Dr Hurst is now Director of Trauma and Critical Care, University of South Florida, Tampa, Florida.

A version of this paper was presented by Mr Campbell during the RESPIRATORY CARE OPEN FORUM during the 37th Annual Meeting of the AARC held December 7-10, 1991, in Atlanta, Georgia.

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Background

Maintaining adequate oxygenation and ventilation during transport of critically ill, mechanically ventilated patients is imperative for a successful result. Work from our institution and others has shown the superiority and enhanced safety of ventilatory support with a portable ventilator during transport, compared to manual ventilation with a self-inflating bag.[1-3] Success also depends upon choice of a ventilator with the appropriate characteristics and capabilities.[4,5] We studied the Impact Uni-Vent 750 portable ventilator* in the

* Suppliers are identified in the Product Sources section at the end of the text.

laboratory and then evaluated its performance during transportation of mechanically ventilated patients from the surgical intensive care unit for diagnostic studies.

Materials and Methods

Description of Device

The Uni-Vent 750 (Fig. 1) is an electronically controlled (microprocessor-controlled), pneumatically and electronically powered ventilator that can be time, pressure, or manually triggered and time

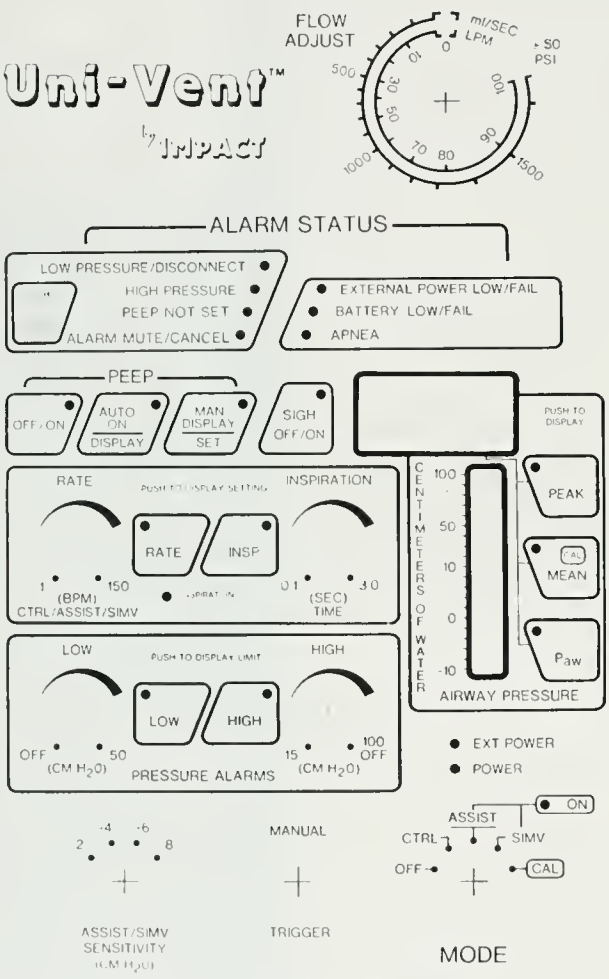

Fig. 1. The Uni-Vent 750 portable ventilator.

or pressure cycled. Ventilator specifications are shown in Table 1 and ventilator alarm and monitoring functions in Table 2. The Uni-Vent 750 weighs 4.3 kg, and its dimensions are 23 cm W × 11.4 cm D × 29.2 cm H. Electric power can be supplied via a multivoltage power supply from continuous AC or DC sources or by two internal 6-volt lead-acid batteries. When the multivoltage power supply unit is connected, the ventilator runs from this power source while continuously charging the batteries. If AC or DC power is disconnected, the External Power Low/Fail alarm illuminates, and the ventilator automatically switches to battery power. The Battery Low/Fail alarm illuminates when the battery is defective and/or when voltage falls below 11 volts, signaling that 1 hour of energy for operation remains. Respiratory rate can be set from 1 to 150 breaths/min and tidal volume is set by selecting the desired combination of inspiratory

Table 1. Specifications for Controlled Variables of the Uni-Vent 750 Portable Ventilator

Variable	Range of Operation
Rate	1-150 breaths/min
Inspiratory time	0.1-3.0 seconds
Expiratory time	0.1-59.9 seconds
F_{IO_2}	100% source gas
Modes	CMV, AMV, SIMV*
Inspiratory flow	0-100 L/min
Sensitivity	−2 to −8 cm H_2O
Sigh	Every 100 breaths or every 7 minutes

* CMV = controlled mechanical ventilation; AMV = assisted mechanical ventilation; SIMV = sychronized intermittent mandatory ventilation.

Table 2. Alarm and Monitoring Functions of the Uni-Vent 750 Portable Ventilator

Alarm	Range
Low pressure/ disconnect	Off-50 cm H_2O
High pressure	15-100 cm H_2O
Inverse I:E	Inspiratory time longer than expiratory time
PEEP not set	Measured PEEP level is ± 2 cm H_2O from set PEEP
Apnea	Ventilator does not cycle for 19 seconds
External power low/ fail	External power source is disconnected or interrupted
Battery low/fail	Battery voltage < 11 volts or bad battery
Peak airway pressure	0-100 cm H_2O
Mean airway pressure	0-100 cm H_2O
End-expiratory pressure	0-20 cm H_2O

time and inspiratory flow. Airway pressure is monitored at the proximal airway by an electronic pressure transducer. Airway pressure can be displayed as a continuous bar graph or in digital form by depressing the appropriate touch key (peak airway pressure, or PIP, and mean airway pressure). Positive end-expiratory pressure (PEEP) is provided by an external PEEP valve. PEEP is monitored by the pressure transducer. There are two methods for allowing sensitivity to be PEEP-compensated during assisted breaths: first, via the auto-PEEP function, which allows the transducer to monitor the end-expiratory pressure and use monitored pressure as a baseline for the sensitivity setting, and, second, via the manual PEEP function, which allows the operator to enter the PEEP value from which triggering should occur. The manual PEEP function is used as a backup to the auto-PEEP function for conditions such as tachypnea, excessive patient movement (artifact), or vibration (seen frequently during helicopter transport) during which time the ventilator may be unable to recognize a stable end-expiratory pressure. Sensitivity is adjustable from –2 to –8 cm H_2O in increments of 2 cm H_2O.

The Unit-Vent 750 provides three modes: control (CMV), synchronized intermittent mandatory ventilation (SIMV), and assist/control (AMV). During SIMV, spontaneous breaths trigger an electronically controlled demand valve that provides gas at the same oxygen concentration as the source. Additionally, a sigh breath can be programmed to deliver a breath at the set flowrate with a 50% increase in inspiratory time (limit 3 seconds) every 7 minutes or every 100 breaths. A manual breath can be initiated by depressing the manual trigger button. During activation of the manual trigger, a breath is delivered at the set flowrate as long as the button is depressed.

The Uni-Vent 750 has adjustable alarms for low and high airway pressure, Apnea, Low Pressure/Disconnect, Inverse I:E, and PEEP-Not-Set alarms (Table 2).

Schematics of the internal components of the ventilator and the patient valve are shown in Figure 2. Compressed gas at 50-90 psi enters the ventilator and is reduced to 50 psi by a single-stage regulator. Gas then travels bi-directionally to the dual inspiratory solenoids and the demand solenoid. During a mechanical breath, the inspiratory solenoids allow gas at the set inspiratory time to travel through the flow control to the patient valve. Redundant solenoids are used as a safety precaution: If one solenoid fails, the other continues normal ventilator operation. During SIMV, when the pressure transducer detects a fall in airway pressure below the sensitivity setting, gas is directed through the demand solenoid to the patient valve. In SIMV, the spontaneous breaths are pressure cycled (the demand valve closes when airway pressure exceeds set end-expiratory pressure).

The patient valve (Fig. 2, bottom) directs gas flow to and from the patient. Gas travels from the ventilator via two separate hoses. Mandatory breaths travel through the main inspiratory circuit through a one-way valve and to the patient, while simultaneously inflating a mushroom (expiration) valve. During expiration, the mushroom valve deflates and gas exits the circuit via the top of the patient valve. When a spontaneous effort is detected during SIMV, gas from the demand valve travels through a 3/16" ID hose to the top of the patient valve. This avoids inflation of the mushroom valve. A third one-way valve serves as an antiasphyxia valve. In the case of gas source failure, the patient can breathe ambient air through this one-way valve. No gas is consumed to power the ventilator. Gas consumption is directly related to patient minute ventilation ($\dot{V}_E$) when using the control or assist/control modes. Gas consumption is

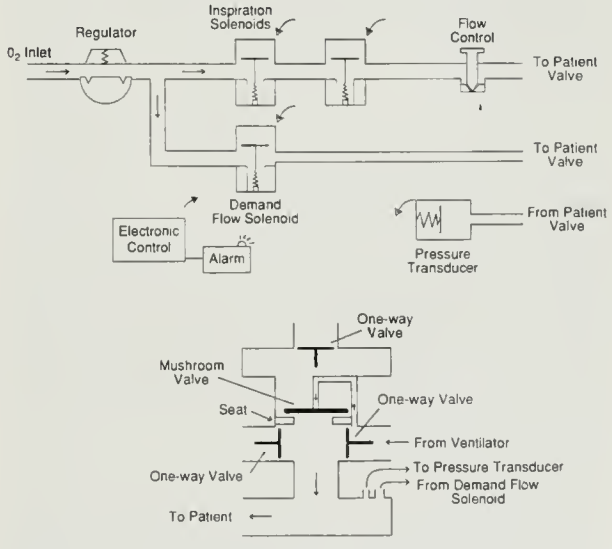

Fig. 2. Schematic of the internal components of the Uni-Vent 750 portable ventilator.

increased slightly in the SIMV mode because the exhalation valve does not close during spontaneous inspiration, thus allowing gas in excess of patient volume to escape during the inspiratory phase. The patient valve is a nondisposable component that must be disassembled and cleaned between patients.

The Uni-Vent 750 is intended for use during inter- and intrahospital transport of mechanically ventilated patients, as initial ventilatory support in the emergency department, and as a simple recovery room ventilator.

Laboratory Evaluation

In the laboratory we evaluated (1) the Uni-Vent 750's ability to deliver the set tidal volume when compliance of a test lung was varied, (2) the responsiveness of the demand valve at PEEP levels up to 20 cm H_2O, and (3) the alarm functions, and determined battery life. The ventilator was set up according to manufacturer's specifications[6] and the pressure transducer calibrated. At initial setup, calibration of the transducer to ambient pressure is necessary for proper ventilator operation. The calibration procedure requires approximately 5 seconds to perform. We set the inspiratory time and flowrate to deliver tidal volumes of 0.05, 0.5, 1.0, and 1.5 L to a test lung (TL) and varied TL compliance from 0.1 to 0.04 to 0.02 L/cm H_2O [1.0 to 0.4 to 0.2 L/kPa]. A pneumotachograph was placed between the TL and patient valve, and delivered tidal volume was recorded. At each combination of tidal volume and compliance, 10 consecutive breaths were recorded to determine mean tidal volume for that tidal volume-compliance combination. The same circuit and patient valve were used for all laboratory tests. We determined the compressible volume of the circuit by injecting gas from a calibration syringe into the circuit in 0.1-L increments until the monitored pressure exceeded 120 cm H_2O. Measured volume was compared to set volume by paired *t* test, and tidal volumes at different compliances were compared by analysis of variance for repeated measures.[7]

We tested the Low Pressure alarm by allowing peak pressure to fall 5 cm H_2O [0.49 kPa] below the alarm setting and tested the High Pressure alarm by allowing PIP to exceed the alarm setting by 10 cm H_2O [0.98 kPa]. We disconnected both the gas source and the patient valve to test the Low Pressure/Disconnect alarm. The Apnea alarm was tested by decreasing the rate to 1 breath/min and discontinuing simulated spontaneous breathing.

Power supply alarms were evaluated by disconnecting the ventilator from the electrical source. After a full night's charge of the batteries, we operated the ventilator until the battery was discharged. We recorded the length of operation and the point at which the Low Battery light illuminated.

Using a TL modified to simulate spontaneous breathing,[8] we evaluated the responsiveness of the demand valve at sensitivity settings of –2, –4, –6, and –8 cm H_2O [–0.2, –0.39, –0.59, and –0.78 kPa]. One side of the TL was ventilated with a Hamilton Veolar ventilator at a tidal volume of 0.5 L, respiratory frequency (f) of 10 breaths/min, peak flowrate of 1.0 L/s, and a sine-wave flow pattern. The Uni-Vent 750 was attached to the opposite side of the TL, which simulates spontaneous breathing. We recorded airway pressure at the patient end of the patient valve during simulated spontaneous breathing at 0, 2.5, 5.0, 7.5, 10.0, 15.0, and 20.0 cm H_2O [0, 0.25, 0.5, 0.74, 0.98, 1.47, and 1.96 kPa]. PEEP was produced by the appropriate PEEP valve, and we allowed the ventilator to choose end-expiratory pressure for triggering using the auto-PEEP function.

Clinical Evaluation

We used the Uni-Vent 750 to provide ventilatory support to 65 patients requiring transportation from the Surgical and Neuroscience Intensive Care Units for diagnostic testing. A description of the patient population is provided in Table 3. Prior to transport, ventilator settings and spontaneous breathing frequency were recorded, and an arterial blood gas analysis was performed. Patients were then placed on the Uni-Vent 750 at settings and mode identical to those of the ICU ventilator except for an F_{IO_2} = 1.0. All patients were ventilated with either a Hamilton Veolar or Puritan-Bennett 7200a ventilator prior to transfer.

During transport, the attending respiratory care practitioner was allowed to manipulate ventilator settings based upon patient need. Any mishaps or problems were noted; immediately prior to return

Table 3. Description and Major Diagnoses for the Patient Population in this Study (n = 65)*

Age	42 (17) years*
Men/women	38/27
Duration of ventilation	5 (3) days
Ventilator frequency	8 (3) breaths/min
Tidal volume	873 (140) mL
Static lung compliance	38 (15) mL/cm H_2O
ARDS/trauma†	21
ARDS/sepsis	13
Closed-head injury	15
COPD and major surgery	6
Repair AAA	4
Miscellaneous surgical	6

* Numbers in parentheses are standard deviations (SD).
† ARDS = adult respiratory distress syndrome; COPD = chronic obstructive pulmonary disease; AAA = abdominal aortic aneurysm.

to the ICU, transport ventilator settings and spontaneous breathing frequency were recorded, and an arterial blood gas analysis was performed. We compared arterial blood gas values and ventilator settings during transport to those in the intensive care units prior to transport by analysis of variance. Statistical analyses were performed with commercially available software.

Results

Laboratory Evaluation

Comparisons of set and delivered tidal volumes (mean and SD) at each compliance are shown in Table 4. There was a tendency for tidal volume to fall as compliance was reduced, and at tidal volumes of 1.0 L and 1.5 L this change was statistically significant as compliance changed from 0.1 L/cm H_2O [1.0 L/kPa] to 0.02 L/cm H_2O [0.2 L/kPa]. Compressible volume of the circuit was only 0.5 mL/cm H_2O, which helps account for the fact that no statistically significant differences were observed between set and delivered tidal volume. At tidal volumes of 0.05 L and 0.5 L, delivered volume was slightly less than set volume, and at volumes of 1.0 L and 1.5 L delivered volumes were slightly greater than set volumes. The significance of these findings is unclear. Low and High Pressure alarms sounded according to manufacturer's specifications and were cancelled when the alarm condition was rectified. Disconnecting either the oxygen source or the patient valve resulted in activation of the Low Pressure/Disconnect alarm. The Apnea and Power Supply alarms also operated according to specifications. Following one night's charging, the ventilator operated from the battery for 10 hours and 8 minutes, and the Low Battery light illuminated at 8 hours and 26 minutes.

Table 4. Comparison of Set and Measured Tidal Volumes

Set V_T (mL)	Compliance 0.1 L/cm H_2O	Compliance 0.04 L/cm H_2O	Compliance 0.02 L/cm H_2O
50	47 (5)*	45 (6)	41 (6)
500	491 (16)	482 (12)	470 (16)
1000	1067 (33)	1012 (30)	989 (31)†
1500	1570 (30)	1502 (26)	1479 (34)†

*Numbers in parentheses are standard deviation (SD).
† $p < 0.05$ compared to V_T at 0.1 L/cm H_2O using ANOVA for repeated measures.

Triggering of the demand valve was accomplished at –2.4 cm H_2O [–0.23 kPa] with the sensitivity set at –2.0 cm H_2O [–0.2 kPa], –4.3 cm H_2O [–0.42 kPa] with the sensitivity at –4.0 H_2O [–0.39 kPa], –6.5 cm H_2O [–0.64 kPa] with sensitivity set at –6.0 cm H_2O [–0.59 kPa] and –8.5 cm H_2O [–0.83 kPa] at a sensitivity setting –8.0 cm H_2O [–0.78 kPa]. We noted that several breaths did not trigger the demand valve at the –8.0 cm H_2O setting, apparently due to ambient air's being drawn into the patient valve via the anti-asphyxia port at this low sensitivity setting. Application of PEEP via a PEEP valve did not affect the trigger sensitivity.

Clinical Evaluation

Results of the clinical evaluation are summarized in Table 5. No statistically or clinically significant changes were seen in any variable except P_{aO_2}. This change occurred and was expected because an oxygen concentration of 1.0 was used during transport. There was a tendency for total $\dot{V}_E$ to be higher during transport, but this was not significant ($p = 0.71$). During these transports, accidental ventilator disconnection occurred on 7 occasions. On each occasion the Low Pressure/Disconnect alarm sounded. Mean transport time was 41 (32) minutes (range 20-252 minutes).

Table 5. Comparison of Ventilator Settings and ABG Values in the ICU vs during Transport

Variable	ICU	Transport
Ventilator f (breaths/min)	8 (3)*	8 (3)
V_T (mL)	873 (140)	873 (140)
PEEP (cm H_2O)	10 (6)	10 (6)
F_{IO_2} (%)	0.52 (0.10)	1.0
PIP (cm H_2O)†	46 (11)	49 (14)
$\dot{V}_E$ (L/min)	8.6 (2.9)	9.2 (2.5)
Spontaneous f (breaths/min)	14 (8)	16 (11)
pH	7.38 (0.04)	7.40 (0.05)
P_{aCO_2}	39 (8)	36 (6)
P_{aO_2}	89 (26)	341 (78)

*Numbers in parentheses are standard deviations (SD).
†PIP = peak inspiratory pressure; $\dot{V}_E$ = minute ventilation.

Discussion

Sophisticated diagnostic and therapeutic procedures performed outside the ICU require that the ICU travel with the patient, mandating dependable, reliable, and portable equipment capable of simulating function of their ICU counterparts. Necessary equipment includes an electrocardiographic (ECG) monitor capable of displaying blood pressures from arterial and pulmonary artery catheters, a portable ventilator, emergency drug box, equipment for airway maintenance, and a stethoscope. The ventilator must combine simplicity, compact size, and portability with versatility and reliability. Because many of the patients transported have severe pulmonary dysfunction, the transport ventilator should be able to mimic the support provided in the ICU.

Several reports have demonstrated the adverse effects of manual ventilation with a self-inflating bag during transport.[1-3,9] Hurst et al,[1] Gervais et al,[3] and Braman et al[2] have all shown that significant respiratory alkalosis is a common complication of manual ventilation. In all three studies, respiratory alkalosis was accompanied by episodic hypotension and cardiac dysrhythmias. Gervais and colleagues demonstrated that hyperventilation can be avoided by monitoring V_T and $\dot{V}_E$ with a portable spirometer.[3] More recently, Weg and Haas[10] have shown that careful attention by an experienced respiratory care practitioner can also avoid iatrogenic hyperventilation and eliminate the need for a transport ventilator. Although we concur, we believe that use of a reliable transport ventilator eliminates the interoperator variability seen when a patient is supported by manual ventilation.[11] Additionally, as a patient is wheeled down corridors, around corners, and into elevators, manual ventilation can be periodically interrupted because the therapist cannot reach the manual resuscitator. We did not examine the cost issue, but because most transport ventilators cost $3,000-$7,000, we believe that over the lifetime of its use the transport ventilator is less expensive than personnel time. It is not our contention that use of a transport ventilator is always better rather than manual ventilation by a well-trained practitioner but that the transport ventilator is as good and is consistent. A survey conducted by our institution in 1985 revealed the characteristics of an ideal transport ventilator:[12] (1) provides IMV; (2) has variable tidal volume; (3) offers a variable rate (2-30 breaths/min); (4) provides a $\dot{V}_E$ of 4-20 L/min; (5) has low and high pressure alarms; (6) provides PEEP (0-20 cm H_2O) [0.2 kPa]; (7) has a demand valve; and (8) monitors airway pressure. PEEP compensation of the demand valve is also desirable. Many of these requests highlighted the shortcomings of current transport ventilators.[4] Although many transport ventilators allow for IMV, spontaneous breaths are supplied through one-way valves from ambient and if PEEP is applied, an expiratory positive airway pressure (EPAP) system develops. This requires that the patient create a negative pressure greater than PEEP prior to opening the one-way valve to the atmosphere. The work of breathing in such a system cannot be tolerated by many ventilator-dependent patients.[13] The desired characteristics listed above are found in the Uni-Vent 750.

The differences between set and delivered V_T in this study are small (< 10%) and clinically unimportant. This is in contrast to the results of the evaluation from our institution of the MAX transport ventilator that demonstrated statistically significant differences in volume delivery as lung compliance was reduced.[5] The differences between the findings in this and the earlier study are probably due to the differences in compressible volume of the ventilator circuits used (0.5 mL/cm H_2O vs 1.4 mL/cm H_2O). In an abstract, McGough and Banner recently reported the effects of changing com-

pliance on volume delivery of 8 transport ventilators.[14] Several of the ventilators tested were incapable of delivering a consistent tidal volume as compliance was reduced. McGough and Banner suggested that this may cause hypoventilation in patients with changing respiratory mechanics and that transport ventilators should provide a constant inspiratory flowrate across a range of possible PIPs and that pressure-limiting valves be clinician adjustable. They also recommended, as our group has in the past,[4,5] that regardless of ventilator reliability, tidal volume be intermittently checked with a portable respirometer during transport to assure adequate volume delivery.

Our evaluation of demand-valve performance demonstrated that the PEEP-compensation algorithm of the Uni-Vent 750 works appropriately. With the sensitivity set at –2.0 cm H_2O [–0.2 kPa] the demand valve was triggered appropriately with PEEP up to 20 cm H_2O [1.96 kPa]. Our finding that, under some conditions, the demand valve doesn't trigger when sensitivity is set lower than –6 cm H_2O [–0.59 kPa] is clinically relevant. This occurs when gas enters the patient valve through the antiasphyxia port and the negative pressure created does not exceed the sensitivity setting. This might occur in a patient with depressed respiration. We recommend that the sensitivity be set at –2 cm H_2O [–0.2 kPa] at all times. This will allow proper triggering of the demand valve and should present the least work of breathing to the patient. If the clinician desires to use a less sensitive setting, the patient should be observed carefully to assure proper demand-valve operation.

During the clinical evaluation, the Uni-Vent 750 provided adequate ventilation and oxygenation to all 65 patients. The only difference in blood gas values between transport and the ICU was in P_{aO_2}. By design, oxygen concentration was set at 1.0 during transport. It is our contention that ventilatory support for short periods of time with an F_{IO_2} of 1.0 poses no harm to adults, and may help prevent desaturation associated with position changes by placing the patient's saturation on the flat portion of the oxyhemoglobin dissociation curve. In the report from our group on the Hamilton MAX Ventilator,[5] PIP was greater during transport than during ventilatory support in the ICU. This was attributed to the fixed 1-second inspiratory time of the MAX. In the Uni-Vent evaluation, we did not observe a change in PIP between the ICU and transport. An increase in spontaneous rate and $\dot{V}_E$ did occur in our patients during transport, which we attribute to the anxiety associated with the procedure. This difference was small and was not statistically significant.

Conclusions

We found the Uni-Vent 750 to be an easy-to-operate, reliable portable ventilator that meets requirements for safe, successful transport of critically ill patients. Although our results demonstrate that tidal volume delivery is relatively constant over a range of lung compliances, actual tidal volume should be measured with a hand-held device. We also recommend that the sensitivity setting remain at –2 cm H_2O [–0.2 kPa]. If sensitivity needs to be reduced, demand-valve function should be carefully observed. Our experience suggests that the Uni-Vent 750 is capable of ventilating even the sickest patients during transport. The ability of the Uni-Vent 750 to provide CMV, AMV, and IMV, the comprehensive alarm system, and PEEP compensation of the demand valve are attributes unique to this portable ventilator.

PRODUCT SOURCES

Calibration Syringe:
Hans-Rudolph, Hans Rudolph Inc, Kansas City MO

PEEP Valve:
Vital Signs Inc, Totowa NJ

Pneumotachograph:
Hans-Rudolph 3200, Hans Rudolph Inc, Kansas City MO

Test Lung:
TTL, Michigan Instruments Inc, Grand Rapids MI

Ventilators:
Uni-Vent 750, Impact Medical Corp, West Caldwell NJ
MAX, Hamilton Medical, Reno NV
Veolar, Hamilton Medical, Reno NV
7200a, Puritan-Bennett Corp, Carlsbad CA

Statistical Software:
Micro Stat, Ecosoft Inc, St Joseph MI

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Evaluation of a Double-Enclosure Double-Vacuum Unit Scavenging System for Ribavirin Administration

Robert M Kacmarek PhD RRT and Joseph Kratohvil RRT

BACKGROUND: Because of our concern for the safety of bedside caregivers who care for infants receiving ribavirin for long periods of time each day for many days, we evaluated the effectiveness of a double-tent enclosure with vacuum scavengers during simulated and actual patient administration. MATERIALS & METHODS: Part 1—We sought to determine whether two or three scavenging pumps were necessary, by 3 8-h trials with 2 pumps and 3 8-h trials with 3 pumps. Entry into and replacement of mannequin occurred according to protocol. Continuous samples were obtained from three locations in the room. Part 2—The double-tent, double-pump scavenger system was evaluated with patient simulation for a 16-h period. Part 3—The double-tent, double-pump system was evaluated during actual patient use. Air samples were also collected during ribavirin administration via mechanical ventilator circuit with filters in the expiratory limb. Coded environmental samples were analyzed by liquid chromatography. RESULTS: Environmental levels were effectively decreased below published maximal acceptable levels. CONCLUSIONS: Use of a double-enclosure, double-pump scavenging system and implementation of entry protocols ensure reduction of environmental ribavirin levels below recommended maximum levels during administration to spontaneously breathing patients. Use of expiratory filters adequately controls environmental ribavirin levels during mechanical ventilation. (Respir Care 1992:37:37-45.)

Background

Ribavirin is an antiviral agent used in aerosol form primarily for the treatment of infants and children with respiratory syncytial virus (RSV) infections. Although its effectiveness in the treatment of RSV infections has been controversial,[1] recent data indicate its usefulness in the management of infants with RSV.[2] Some have recommended its use in the treatment of RSV infections in infants with congenital cardiac disease, immunosuppression, or bronchopulmonary dysplasia, and in any infant who is judged to be critically ill at presentation, regardless of the need for mechanical ventilation.[3]

Aerosols of ribavirin should have a mass median aerodynamic diameter of 1.3 μ to deposit on the lung parenchyma of small infants and require accumulation over time to be effective.[4] Therefore, the drug is usually administered continuously over an 18-20 hour period for 3-7 consecutive days.[4] Because many infants receiving ribavirin are not intubated, environmental contamination is unavoidable if conventional administration procedures are used. The presence of detectable levels of the drug in the patient-care environment has raised the concern of health-care workers because ribavirin has been shown to be teratogenic in small mammals,[5-9] although no such effects have been noted in baboons following 120 mg/kg administered during critical periods of gestation.[8]

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ICN Pharmaceuticals Inc states that the administration of the drug at therapeutic doses is contraindicated in women who are or may become pregnant during exposure to the drug, although limited data are available on the actual reproductive effect of ribavirin on humans.[4] The company also recommends that women with known pregnancy be informed of the potential risk and not enter the immediate area of aerosol administration, thereby avoiding incidental exposure. Although analysis of blood and urine from respiratory therapists and nurses incidentally exposed to ribavirin over periods of 8-12 hours has resulted in detection in only one nurse,[10-12] the subjects studied were exposed to ribavirin for only 1 to 3 days, whereas caregivers are frequently exposed to ribavirin on an almost daily basis during RSV season (about 90 days). Ribavirin is phosphorylated and sequestered in red blood cells and not cleared from the body for a 4-week period.[4] Although red blood cells normally do not cross the placenta, the effects of chronic exposure have not been evaluated. Ribavirin is also highly water soluble and is distributed throughout the body. The fluid assay detection limit of ribavirin is 0.02 μg/mL. Thus, ingestion of over 2,000 μg, when distributed through the entire body in the average adult, is well below the detection limit.[11] In addition, our practitioners and others[11,13] have complained about tracheal, pharyngeal, bronchial, nasal, and conjunctival irritation from exposure to aerosolized ribavirin.

Based on the potential and real concerns regarding exposure to aerosolized ribavirin, we evaluated a double-tent enclosure with vacuum scavengers,* using the ICN hood and a Goss Care Cube to eliminate environmental levels of ribavirin during simulated and actual patient administration. In addition, we evaluated the use of Pall filters in the expiratory limb of ventilator circuits to prevent ribavirin leak during mechanical ventilation. Our goal was to reduce the time-weighted average (TWA) exposure of practitioners over an 8-hour period to below the maximal level of exposure (2.7 μg/m^3 TWA) recommended by the California Department of Health[14] and the Massachusetts Department of Labor and Industries.[15]

* Suppliers are identified in the Product and Service Sources section at the end of the text.

Materials and Methods

All administrations of ribavirin, whether simulated or to patients, were conducted in negative-pressure isolation rooms (negative to corridor) with a separate air circulating system ensuring at least 6 room-air exchanges per hour and equipped with high efficiency particulate air (HEPA) filters. Evaluation during spontaneous breathing was divided into three parts. During Part 1, two different double-tent systems were evaluated over an 8-hour period. In Part 2, the use of a double-tent, double-vacuum scavenger system over a 16-hour period was evaluated. In Part 3, the double-tent, double-scavenger system was evaluated during actual patient use.

During all administrations of ribavirin, airborne ribavirin samples were collected on Gelman 37-mm glass-fiber filters with a cellulose ester back-up pad in a two-piece cassette, using an Air-Chek air sampler. Prior to and after sampling, each pump was calibrated with an Accuflow digital flowmeter. Sampling flows were maintained at 2 and 3 L/min. During the lengthy sampling periods of Parts 2 and 3, the sampling pumps were not run by battery but were operated on standard alternating current.

All environmental filter samples were sent under blinded code to ICN Pharmaceuticals. Analysis was performed using high performance liquid chromatography according to NIOSH Method 5027. The limit of ribavirin qualitative quantification was 1.25 μg/collection filter, with ±50% accuracy at this level. Below 1.25 μg, the analysis indicated a trace amount that we report conservatively as 1.25 + 50% or 1.88 μg/filter. With each group of filters analyzed, blank filters never exposed to ribavirin and filters saturated with ribavirin were sent for analysis. All blanks were analyzed as no ribavirin present and all saturated filters analyzed as large quantities of ribavirin present (approximately 100 μg/filter).

The final setup for administration and scavenging of ribavirin is depicted in Figure 1. During specific trials in Part 1 of this study, the intake tube of a third vacuum scavenger was inserted into the rear panel of the cube tent parallel to the intake tube of the vacuum scavenger shown at the top of the tent in Figure 1. Otherwise, all setups used were as depicted in Figure 1. The ICN hood was

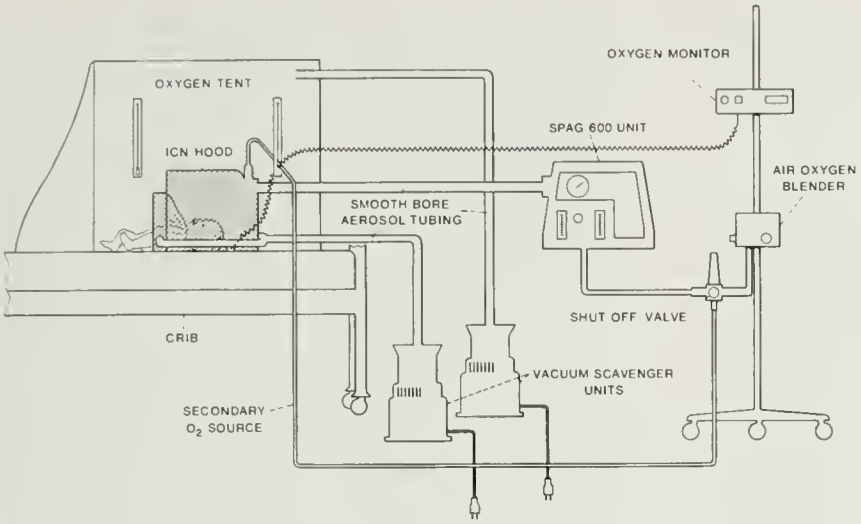

Fig. 1. Double-tent, double-vacuum scavenging system used for the administration of aerosolized ribavirin to spontaneously breathing infants. An ICN ribavirin scavenging hood is placed inside a Goss Care Cube tent. One ICN HEPA-filtered vacuum scavenger is attached to the ICN hood; the other to the back panel of the cube tent. A secondary oxygen source and oxygen analyzer probe are placed inside the ICN hood. Blended gas via a shut-off valve is directed either to the SPAG-2 unit or the secondary oxygen source. See text for additional detail.

placed inside the cube tent. Aerosol entry into the hood was from the back of the cube tent. Scavenging from the ICN hood also occurred from the rear of the cube tent. The first two vacuum devices were inserted into the cube tent approximately 6 inches from the top of the tent and in the center of the back panel. As noted in Figure 1, an oxygen analyzer probe was inserted into the ICN hood throughout the treatment, as was an oxygen connecting tubing attached to the same blender powering the Small Particle Aerosol Generator (SPAG-2) producing the ribavirin aerosol. A control valve was placed on the gas source entering the SPAG-2 to allow for immediate termination of the function of the SPAG-2 unit. The oxygen connecting tubing was attached to a flowmeter to allow for continued oxygen delivery when the SPAG-2 was turned off.

The volume of gas drawn through the ICN vacuum scavengers was assessed by a hot-wire anemometer. Three independent measurements were made on each of four different scavenger units. Five-foot lengths of 22-mm large smooth internal bore tubing were connected to each pump. Smooth internal bore tubing was used to minimize turbulence and maximize flow. A single-use HEPA filter connected the large-bore tubing to the scavenger unit. One filter operated on each scavenger for the length of each trial.

During all trials, a solution of 6 g of ribavirin in 300 mL of sterile water was nebulized at a driving flow of 7.5 L/min for the duration of the trial. The drying chamber was also operated at 7.5 L/min for all spontaneous breathing trials.

Part 1

This initial phase of the study was designed to determine whether two or three vacuum scavenging pumps were needed. Three 8-hour trials with 2 scavengers and 3 8-hour trials with 3 scavengers were performed on separate days. During each of these trials, a series of simulated entries into the enclosure were performed during which a baby mannequin was removed for 5 minutes and then replaced. Table 1 shows the protocol followed during each of these tent entries. Note that the vacuum scavenging devices were never stopped during the 8-hour trial. Three air sampling pumps with filters were placed in the room and run continuously for the 8-hour testing period. One pump was placed at the entrance of the room at a 5-foot level, a second pump was placed at the front of the tent on the side

Table 1. Protocol for Planned Entry and Replacement Entry into Ribavirin Delivery Enclosures

For Planned Entry:
Turn on secondary oxygen source.
Turn off SPAG unit.
Wait 5 minutes.
Enter tent.
For Replacement Entry:
Place child into ICN hood.
Seal cube tent with blanket.
Turn on SPAG unit.
Turn off secondary oxygen source.

of the bed at a 5-foot level, and the third pump was placed at the front of the tent on the side of the bed, 6 inches above bed level.

Part 2

Based on the results of Part 1, we decided that two vacuum scavengers were sufficient to remove the ribavirin aerosol. However, because aerosols concentrate with time, we believed that it was necessary to evaluate the TWA exposure over the normal length of treatment (approximately 18-20 hours). Three 16-hour trials were performed. During the last trial, the effects of both emergency and scheduled entry into the tent were evaluated. The procedure used for emergency entry is outlined in Table 2. Sampling pumps with filters were placed at the same locations as in Part 1.

Table 2. Protocol for Emergency Entry into Ribavirin Delivery Enclosures

Reach under tent opening, keeping front enclosure flap down and your head outside of cube tent. (If possible, turn SPAG off before entering tent.)
Remove child completely from both tents.
Close tent opening.
Turn off SPAG unit.

Part 3

The double-tent, double-scavenger protocol used in Part 2 (Fig. 1) was used during treatment of three infants requiring ribavirin. During treatment, scavengers and air sampling devices were run continuously, even when the child was out of the tent. However, based on data from Parts 1 and 2, air sampling was performed only at the front of the tent on the side of the bed, 6 inches above the bed level. Procedures for tent entry and replacement, as outlined in Tables 1 and 2, were followed.

Mechanical Ventilation

Air samples were also collected during the administration of ribavirin via a Sechrist infant ventilator. The setup used was that previously outlined by Adderley.[16] The delivery tube of the SPAG-2 opened into the inspiratory limb of the ventilator circuit. A one-way valve was placed just before the junction to prevent back flow during pressure-plateau ventilation. A Pall filter was placed in the expiratory limb just proximal to the exhalation valve. During treatment, flow to the drying chamber was shut off; only gas from the nebulizer entered the ventilator circuit. The total flow from the Sechrist was decreased by 7.5 L/min, the flow entering the circuit from the SPAG-2 unit. In addition, the patient's cuffless endotracheal tube was sized to eliminate leak about the cuff. Prior to disconnection of the ventilation, the SPAG-2 unit was turned off and the flow through the Sechrist adjusted appropriately, for a period of at least 1 minute, before being disconnected from the airway. If emergency disconnection was required, the endotracheal-tube circuit adapter was immediately capped after disconnection. During these treatments, one air sampling unit was placed at the head of the bed, 6 inches from bed level and about 12-18 inches from the endotracheal tube.

Results

Data from Parts 1, 2, 3, and during mechanical ventilation, are presented in Tables 3, 4, 5, and 6. Table 7 presents results of the evaluation of the flow of gas (L/min) drawn from each of four vacuum scavenger units. All tables list the time the scavengers were operational or the total time from the beginning of the treatment to completion. In Table 5, Trials 1 and 2 were on a single patient and Trials 3 and 4 were on separate patients. In Table 6, the two trials were on two different patients.

The identification of trace quantities of ribavirin represent 1.25 ± 0.625 μg. We used a conservative estimate of the total drug scavenged, or 1.88 μg (the upper limit of measurement error), for our determination of room concentration when trace amounts were identified. The method used to calculate the room concentration as a TWA for the total time of the treatment is shown in Figure 2.

Discussion

Our findings indicate that environmental levels of ribavirin during administration by tent or mechanical ventilator can be effectively decreased

Table 3. 8-Hour Double-Tent Ribavirin Trials with 2 and 3 Vacuum Pumps—Part 1

Run (No.)	Scavenger Pumps (No.)	Scheduled Entries (No.)	Pump Flow (L/min)	Filter Weight (μg)	Sampling Pump Location	Room Concentration* (μg/m³)
1	3	4	3.10	Trace†	Door-5 ft	1.26
1	3	4	2.85	Trace	Bed level	1.37
1	3	4	2.95	Trace	Bed-5 ft	1.33
2	2	3	3.13	Trace	Bed- 5ft	1.25
2	2	3	2.98	Trace	Bed level	1.31
2	2	3	3.02	Trace	Door-5 ft	1.30
3	3	4	2.93	Trace	Bed level	1.34
3	3	4	2.86	ND‡	Bed-5 ft	1.37
3	3	4	2.94	ND	Door-5 ft	1.33
4	2	4	2.93	ND	Door-5 ft	1.34
4	2	4	3.15	ND	Bed-5 ft	1.34
4	2	4	2.81	Trace	Bed level	1.39
5	3	4	2.82	Trace	Door-5 ft	1.39
5	3	4	3.10	Trace	Bed level	1.26
5	3	4	2.91	Trace	Bed-5 ft	1.35
6	2	4	3.15	Trace	Door-5 ft	1.24
6	2	4	2.89	Trace	Bed-5 ft	1.36
6	2	4	2.96	Trace	Bed level	1.32

* Based on sampling time of 480 min and a concentration reflecting maximal (50%) error (1.88 μg/filter).

† Trace = 1.25 ± 0.625 μg/filter, maximum potential level 1.88 μg/filter.

‡ ND = none detectable.

below published maximal acceptable levels by the use of a double-tent enclosure system or Pall filters in the expiratory limb of the ventilator circuit and by implementation of caregiver protocols for entry into these systems. These data are in agreement with information published by Charney et al[17] who used a similar setup, with an oxygen hood (Tot Hut) for the inner enclosure. Charney et al[17] were unable to detect any drug on collection filters placed in the room or on personnel, whereas we collected trace amounts (1.25 ± 50% μg/filter) on all but one filter. The one sample greater than trace was collected during Part 2, when 7 emergency entries into the enclosure were simulated. It is unlikely that 7 emergency entries would be necessary in a normal 16-hour period. However, even on this trial, the TWA ribavirin level was well below recommended maximum levels. We believe that the difference between our data and that of Charney et al[17] is a result of the detection limit used in filter analysis by Charney et al,[17] as compared to ours. The qualitative limit of quantitation of our samples was 1.25 + 50% μg, while Charney et al's varied from sample to sample and reached a high of 2.36 μg (extrapolated from data presented in paper). As a result, if Charney et al's data had been analyzed by the same instrumentation as ours, similar data might have been obtained. Both our data and Charney et al's demonstrate much greater environmental control than that possible by the use of the ICN hood without a secondary enclosure. Corkery et al[18] determined an environmental TWA of 29.3 μg/m³ with the use of the ICN hood alone.

The maximum acceptable environmental level of ribavirin has been estimated by the California Department of Health[14] and adopted by Massachusetts Department of Labor and Industries.[15] The maximum TWA exposure of 2.7 μg/m³ over an

Table 4. 16-Hour Double-Tent Ribavirin Trials with 2 Vacuum Pumps and Scheduled and Emergency Entries—Part 2

Run (No.)	Scavenger Pumps (No.)	Scheduled Entries (No.)	Emergency Entries (No.)	Pump Flow (L/min)	Filter Weight (μg)	Sampling Pump Location	Room Concentration ($\mu g/m^3$)
7	2	7	0	2.40	Trace*	Door-5 ft	0.82†
7	2	7	0	2.40	Trace	Bed level	0.81†
7	2	7	0	2.50	Trace	Bed-5 ft	0.78†
8	2	7	0	2.33	Trace	Bed level	0.84†
8	2	7	0	2.38	Trace	Bed-5 ft	0.82†
8	2	7	0	2.46	ND‡	Door-5 ft	0
9	2	3	7	2.48	ND	Bed-5 ft	0
9	2	3	7	2.44	ND	Door-5 ft	0
9	2	3	7	2.28	1.41 ± 0.705	Bed level	0.97§

* Trace = 1.25 ± 0.625 μg/filter, maximum potential level 1.88 μg/filter.

† Based on sampling time of 960 min and a concentration reflecting maximal (50%) error (1.88 μg/filter).

‡ ND = none detectable.

§ Based on sampling time of 960 min and a concentration of 2.12 μg/filter.

8-hour period is based on the "no observed effect level" (NOEL) in the most sensitive animal species studied. The NOEL level for ribavirin is 0.3 mg/kg, based on data from rabbits.[8] In relating the NOEL level to humans, the Occupational Safety and Health Administration applies a safety factor of 100 to 1,000 to animal data. Because the results on rabbits were not determined from chronic studies, a factor of 1,000 has been applied to the rabbit data[16] or a maximum exposure level of 0.3 μg/kg/day. To convert this value into an average environmental concentration of ribavirin, a number of assumptions were made. The typical employee exposed to the drug weighs 58 kg, breathes at a minute volume of 19 L over the 8-hour exposure period, and retains 70% of the inspired drug, or a TWA average exposure of 2.7 $\mu g/m^3$ over an 8-hour period.

Table 5. Actual Patient Data with Double-Tent Ribavirin Administration

Run (No.)	Scavenged Time (min)	Pump Flow (L/min)	Filter Weight (μg)	Pump Location	Room Conc* ($\mu g/m^3$)
1	1110	2.48	Trace†	Bed level‡	0.683
2	1200	2.68	Trace	Bed level	0.585
3	1140	2.30	Trace	Bed level	0.717
4	1080	2.65	Trace	Bed level	0.657

* Based on a sampling time of 1,080-1,200 minutes and a concentration reflecting maximum sampling error of 50% (1.88 μg/filter).

† Trace = 1.25 ± 0.625 μg/filter, maximum potential level 1.88 μg/filter.

‡ 12 inches from tent, 6 inches above mattress level.

Table 6. Actual Patient Data during Mechanical Ventilation with Expiratory Filter in Place

Run (No.)	Scavenged Time (min)	Pump Flow (L/min)	Filter Weight (μg)	Pump Location	Room Conc ($\mu g/m^3$)
1	1200	2.42	Trace*	Bed level†	0.647
2	1320	2.58	Trace	Bed level	0.552

* Trace = 1.25 ± 0.625 μg/filter, maximum potential level 1.88 μg/filter.

† 12 inches from endotracheal tube, 6 inches above mattress level.

Table 7. ICN Vacuum Scavenger Pump Continuous Flow

Pump (No.)	Trial 1 (L/min)	Trial 2 (L/min)	Trial 3 (L/min)	Mean (SD) (L/min)
1	192	186	185	187.7 (3.8)
2	182	181	183	182 (1.0)
3	190	181	188	186.3 (4.7)
4	182	182	187	183.7 (2.9)

Determination of Time Weighted Average

$$\frac{\text{ribavirin weight on filter in } \mu g}{(\text{scavenger time})(\text{pump flow})} = \mu g/L$$

$$(\mu g/L)(10^3\ L/m^3) = \mu g/m^3$$

Example : Calculation for Trial 1, Table 3

$$\frac{1.88\ \mu g/\text{filter}}{(480\ \text{min})\ (3.10\ L/\text{min})} = 0.00126$$

$$\frac{0.00126\ \mu g}{L} \times \frac{10^3\ L}{m^3} = 1.26\ \mu g/m^3$$

Fig. 2. Calculation of time-weighted average (TWA) exposure from measured variables.

These assumptions are very conservative but are meant to provide protection for the most sensitive health-care worker exposed to the drug.

Of concern during the performance of this study was the potential for reducing the concentration of ribavirin in the inner enclosure by actively drawing gas from this enclosure, instead of passively allowing gas to exit. We evaluated the effect of the double-vacuum scavengers on the ICN hood by establishing an oxygen concentration of 0.40 within the ICN hood (using oxygen connecting tubing) and then noting the oxygen concentration change when the scavengers were activated. At most, ± 2% concentration change was noted, consistent with changes occurring clinically in all oxygen hoods. In addition, the 22-mm circular opening in the ceiling of the cube allowed for room air to be drawn into the cube tent by the scavenger pumps. We noted the sides of the cube tent were somewhat concave when the scavengers were activated, instead of convex, as during normal tent therapy.

As noted in Table 7, the volumetric flow through each scavenger pump was about 185 L, for a total draw of 370 L. The total volume of the double-tent enclosure is about 0.7 m^3 or a 700-L volume. The high draw from the scavengers was necessary to maintain airflow currents into the tent, thus preventing leakage to the environment in spite of system leaks (emergency entries) and a total flow of 15 L/min into the enclosure from the SPAG-2 unit.

The use of large-bore tubing with a smooth internal surface is essential for maximal efficiency of the scavenger pumps. Anything that creates increased resistance to flow modifies the volume of gas drawn through the scavenger units. In our tests, the use of conventional corrugated tubing markedly decreased flow. Even the use of flow-measuring devices with inertia and minimal resistance (eg, the Wright respirometer) dramatically decreased the flow measured, compared with the flow measured by hot-wire anemometer.

The use of a cutoff valve on the SPAG-2 unit is essential for maximum efficiency of this system. We now use a cutoff valve provided by ICN Pharmaceuticals that allows us to immediately stop flow to the SPAG-2 and open flow from the secondary oxygen source. This allows all health-care workers to rapidly inactivate the SPAG-2, provide supplemental oxygen, and then re-establish SPAG-2 flow without adjusting the SPAG-2 unit.

Table 6 shows the environmental levels of ribavirin measured when ribavirin was administered via a mechanical ventilator. The placement of a Pall filter in the expiratory limb, the use of an appropriately fitted endotracheal tube, and the shutting off of the SPAG-2 at least 1 minute before disconnection of the ventilator system prevents ribavirin from entering the room. However, whenever ribavirin is administered via a mechanical ventilator, care must be exercised to ensure that the child is adequately ventilated throughout the ribavirin treatment. Ribavirin crystallizes in the ventilation circuit and endotracheal tube, and clogs the expiratory filter if precautions are not taken. We changed the expiratory filter every 4 hours and the ventilator circuit every 8 hours, and we instilled normal saline solution into the endotracheal tube every hour to prevent tube obstruction and ensure proper function of the ventilator system. If these precautions are taken, ribavirin can be safely administered to mechanically ventilated patients.

Table 8 shows the initial and daily cost of using this double-enclosure system. Although the daily cost of disposables is relatively high, it is much less than the list price of a single dose of ribavirin

($425), and we believe the costs are a small price to pay to ensure that caregivers are appropriately protected from the real and potential hazards of the drug.

Table 8. Cost of Administering Ribavirin with Double-Tent, Double-Scavenging System

Nondisposables, Initial Cost (List Price)		
ICN Hood #4030-01		$225.00
Vacuum Scavengers #4031-01 ($162 x 2)		324.00
	Total Intial	$549.00
Disposables, Daily Cost (List Price)		
HEPA filter #4032 ($21.25 x 2)		$42.50
Hudson smooth-bore tubing #1417 ($2.50 x 3)		7.50
Goss Care Cube tent #4500		17.50
Airlife oxygen connecting tubing #001301		1.04
Airlife 22-mm 18-in tubing #1424		1.14
Airlife T-connector #1500		0.65
ICN Hood Collar #4033-01		6.00
	Total Daily	$76.33

Our present protocols during the administration of ribavirin include those outlined in Tables 1 and 2. In addition, the drug is administered only in negative-pressure HEPA-filtered isolation rooms, with at least six complete room-air turnovers per hour. All personnel tending the infant or handling bedding are required to gown and mask. The amount of time spent in the room by any health-care worker is limited. Bedding is changed after completion of the daily treatment. Treatments are scheduled to ensure that time out of the tent occurs during normal visiting hours. Family members are alerted to concerns regarding ribavirin and pregnancy.

Conclusion

The use of the ICN hood and the Goss Care Cube tent with two ICN scavengers and adherence to administrative protocols ensures the reduction of environmental levels of ribavirin below recommended maximum levels. We have found this system reasonably easy to use and rapidly accepted by all health-care workers interacting with infants who require treatment with ribavirin. We have also demonstrated that if expiratory filters, properly sized endotracheal tubes, and administrative protocols are followed, environmental levels are maintained below maximum recommended levels when ribavirin is administered via a mechanical ventilator.

We believe that if real or potential hazards exist for caregivers as a result of exposure to a therapeutic agent, maximum efforts should be made to minimize, with the goal to eliminate, environmental levels of the agent in question.

PRODUCT AND SERVICE SOURCES

Air Sampling Equipment:
- Sample cassettes, Gelman 37-mm glass-fiber filters with cellulose ester backup pad
- Air-Chek air sampler, Model 224-43XR, SKC Inc, Eighty-Four PA
- Accuflow digital flowmeter film calibrator, SKC Inc, Eighty-Four PA

Scavenging Equipment:
- Vacuum Pumps, #4031-01, ICN Pharmaceuticals, Costa Mesa CA
- Smooth-bore tubing, #1417, Hudson-RCI, Temecula CA
- HEPA filter #4032, ICN Pharmaceuticals, Costa Mesa CA
- One-way valve (for SPAG delivery tube), #BE-117 Non-Rebreathing "T," Instrumentation Industries, Bethel Park PA
- Pall filter (expiratory), #BB50T, Pall Biomedical, East Hills NY

Patient Enclosures:
- Hood #40301, ICN Pharmaceuticals, Costa Mesa CA
- Goss Care Cube tent #4500, RE Goss, Alsip IL

Analytical Services:
- High-performance liquid chromatography, ICN Pharmaceuticals, Costa Mesa CA

Flow-Assessing Device:
- Hot-wire anemometer MPM 500, Thermo-HygroTacho-Anemometer, Solomat Corp, Stamford CT

Aerosol Generator:
- SPAG-2 aerosol generator, ICN Pharmaceuticals, Costa Mesa CA

Mechanical Ventilator:
- Sechrist infant ventilator, IV-100B, Sechrist Industries, Anaheim CA

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Analysis of Job Satisfaction, Burnout, and Intent of Respiratory Care Practitioners To Leave the Field or the Job

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BACKGROUND: Increased stress, burnout, and lack of job satisfaction may contribute to a decline in work performance, absenteeism, and intent to leave one's job or field. We undertook to determine organizational, job-specific, and personal predictors of level of burnout among respiratory care practitioners (RCPs). We also examined the relationships among burnout, job satisfaction (JS), absenteeism, and RCPs' intent to leave their job or the field. METHODS: A pilot-tested assessment instrument was mailed to all active NBRC-credentialed RCPs in Georgia (n = 788). There were 458 usable returns (58% response rate). A random sample of 10% of the nonrespondents (n = 33) was then surveyed by telephone, and the results were compared to those of the mail respondents. Variables were compared to burnout and JS scores by correlational analysis, which was followed by stepwise multiple regression analyses to determine the ability of the independent variables to predict burnout and JS scores when used in combination. RESULTS: There were no significant differences between respondents and sampled nonrespondents in burnout scores (p = 0.56) or JS (p = 0.24). *Prediction of burnout:* The coefficient of multiple correlation, R^2, indicated that in combination the independent variables accounted for 61% of the variance in burnout scores. The strongest predictor of burnout was job stress. Other job-related predictors of burnout were size of department, satisfaction with work, satisfaction with co-workers and co-worker support, job independence and job control, recognition by nursing, and role clarity. Personal-variable predictors were age, number of previous jobs held, social support, and intent to leave the field of respiratory care. *Prediction of job satisfaction:* R^2 indicated that, in combination, the independent variables accounted for 63% of the variance observed in satisfaction with work, 36% of the variance observed in satisfaction with pay, 36% of the variance in satisfaction with promotions, 62% of the variance in satisfaction with supervision, and 48% of the variance in satisfaction with co-workers. Predictors of work-satisfaction level were recognition by physicians and nursing, age, burnout level, absenteeism, and intent to leave the field. Predictors of level of satisfaction with pay were actual salary, job independence, organizational climate, ease of obtaining time off, job stress, absenteeism, intent to leave the field, and number of dependent children. Predictors of level of satisfaction with promotions were recognition by nursing, participation in decision making, job stress, intent to leave the field, past turnover rates, and absenteeism. Predictors of level of satisfaction with supervision included supervisor support, role clarity, independence, and ease of obtaining time off. The strongest predictor of level of satisfaction with co-workers was co-worker support. As overall level of JS increased, level of burnout decreased significantly ($r = -0.59$, $p < 0.001$). As burnout level increased, increases occurred in absenteeism ($r = 0.22$, $p < 0.001$), intent to leave the job ($r = 0.48$, $p < 0.001$), and intent to leave the field ($r = 0.51$, $p < 0.001$). CONCLUSIONS: Reduced job stress, increased job independence and job control, improved role clarity, and higher levels of JS were all associated with lower levels of burnout. Managerial attention to these factors may improve patient care and reduce absenteeism and turnover among RCPs. (Respir Care 1992;37:46-60.)

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Background

Concern has recently been expressed in the health-professions literature about job satisfaction, burnout, employee retention, and employee turnover.[1-4] This concern extends to respiratory care.[5-12] Research indicates that increased stress, burnout, and a lack of job satisfaction contribute to high turnover rates in the health professions.[4,13-15] This in turn may exacerbate manpower shortages.

Stress and Burnout

Staff burnout in the health professions has been defined as a syndrome of physical and emotional exhaustion involving the development of negative job attitudes, a poor self-concept, and a loss of concern for patient welfare.[16-20] Burnout is thought by some[10-20] to be a cause of turnover, absenteeism, declines in the quality of patient care, and other adverse job outcomes. If specific environmental, organizational, or job-related factors or personal variables are associated with increased or decreased burnout, intervention or prevention may be possible.[21-23]

In the first published work (1974) on burnout in the health and human-service fields, Freudenberger described burnout as "to fail, wear out or become exhausted by making excessive demands on the energy, strength or resources" of human-service workers.[24] Burnout is thought by some[20,22-24] to be caused by excessive job stress. Major categories of variables associated with the development of burnout include organizational factors, job-specific factors, and demographic, personal, and professional variables.[22]

We (Shelledy and Mikles) have examined the relationships among demographic variables, job-related variables, and staff burnout in a sample of 70 respiratory care practitioners (RCPs).[5] Burnout levels among those RCPs were similar to levels found in nursing and other allied health professions. The level of professional education, quality of the respiratory care department, job freedom, and job independence were all significantly related to the degree of professional burnout observed. In combination, the demographic and job-related variables examined accounted for 18% of the variance in burnout observed ($R = 0.42$, $p = 0.02$).

In a study of 71 RCPs, Rawlins sought to determine the relationships among job stress, job dissatisfaction, and intent to leave the field.[6] He found significant positive correlations between most potential stressors and dissatisfaction with the work itself. Job dissatisfaction and stress-index scores were able to predict intent to leave the field for 82% of the subjects. Rawlins concluded that the major factors associated with the decision to leave the field of respiratory care were dissatisfaction with supervision, dissatisfaction with co-workers, and role, goal, and financial stress.

Job Satisfaction (JS)

Job satisfaction (JS) has been described as the "attitudes and feelings a person has about work."[25] A number of researchers have investigated JS among health-care workers.[26-33] As with burnout, JS is thought to affect the quality of work performance, productivity, turnover, absenteeism, and other job outcomes.[34-40]

Our review of the literature revealed three studies of JS among RCPs.[7-9] Akroyd and Robertson sought to determine factors associated with overall JS among RCPs.[7] They surveyed a random sample of 10% of the registered respiratory therapists in nine southeastern states. Five aspects of JS were assessed by use of the Job Descriptive Index (JDI): satisfaction with the work, pay, promotions, supervision, and co-workers. According to Akroyd and Robertson, "these facets are part of Overall Job Satisfaction." However, it is not clear how an overall JS score was determined in their study. The JDI does not have an overall JS scale, although a summed score of the five subscales is sometimes used to derive overall JS.[41] Of the variables examined by Akroyd and Robertson, only levels of satisfaction with work and satisfaction with supervision contributed significantly to the prediction of JS.

Akroyd and Robertson believe that "if the more critical components of the work environment can be identified, we may be able to more effectively influence the therapist's perception of his job and his performance and, thus, the quality of respiratory care."

Hmelo and Axton surveyed 188 RCPs from 18 randomly selected hospitals.[8] They examined the relationships among variety of tasks performed,

task complexity, and the five aspects of JS assessed by the JDI. They found no relationships between variety of tasks performed or task complexity and levels of satisfaction with pay, promotions, supervision, or co-workers. There was a positive relationship between performance of an increasing variety of tasks and increased satisfaction with work; however, with an increase in the number of complex tasks performed, satisfaction with the work declined. Hmelo and Axton concluded that "the respiratory care practitioner's job satisfaction may be influenced positively by the diversity and negatively by the complexity of tasks performed."

In a study of 199 respiratory care technical directors in Texas,[9] Burke, Tompkins, and Davis examined the relationship between role conflict and JS and between role ambiguity and JS. They found significant negative correlations between role conflict and JS and between role ambiguity and JS. As role conflict or role ambiguity increased, JS declined.

Purpose of Our Study

Our purpose was to determine the organizational, job-specific, and personal predictors of levels of JS, burnout, absenteeism, and employee intent to leave the job or field among RCPs in the state of Georgia. The relationship between JS and burnout was also to be examined. If certain of the foregoing variables were found to be associated with higher or lower levels of burnout and/or JS, the possibilities for prevention or remediation would be enhanced. This in turn might improve employee retention, absenteeism, productivity, and patient care.

We used a correlational research design,[42:327-330] which included multiple regression analysis, to address the following hypotheses:

1. Specific organizational and job-related factors in the workplace are associated with significantly increased levels of staff burnout and decreased levels of JS among RCPs.

2. Specific demographic, professional, and personal characteristics of the individual RCP are associated with significantly increased levels of staff burnout and decreased levels of JS among RCPs.

3. As JS increases among RCPs, there will be a significant decrease in level of burnout.

4. As burnout level increases and JS level declines, there will be a significant increase in absenteeism and turnover.

Study Methods

Population and Sample

The population comprised all active NBRC-credentialed RCPs (n = 788) in the state of Georgia.[43] The study instrument was mailed to each member of the population. Two subsequent mailings were performed to try to increase the response rate. We received 458 usable returns (58% response rate). Following the third mailing, the study instrument was administered by telephone to a random sample of 10% of the nonrespondents (n = 33). Mean burnout and JS scores from this subsample were compared to those of the mail respondents, using a *t* test. The absence of a signif-icant difference would indicate that the respondents and nonrespondents were similar in these scores, suggesting that the sample was representative of the population.

The Instrument

The assessment instrument had three parts. Part I consisted of the Job Analysis Survey for Respiratory Care Practitioners (JAS-RCP) that was developed and pilot-tested as a part of this study. This part of the instrument had 76 items constructed to assess organizational factors; job-specific variables; demographic, professional, and social-support variables; and two outcome variables: intent to leave the job or field, and absenteeism. Items used to assess attitudes about work used a six-step rating scale.[44:594-602] Two or more items were used to assess each attribute, and the summated scale score for these items was used for analysis.[44:594-602] For example, to assess the level of job stress, the participant was asked to rate the following two items, using the scale shown:

"The level of stress at work is high"

Agree Very Much	Agree Pretty Much	Agree a Little	Disagree a Little	Disagree Pretty Much	Disagree Very Much

and

"I find my job to be stressful"

Agree Very Much	Agree Pretty Much	Agree a Little	Disagree a Little	Disagree Pretty Much	Disagree Very Much

Participants' responses to each item were scored from 1 (Disagree Very Much) to 7 (Agree Very Much). An even number of steps was used to avoid a neutral response to an item.[44:596] The scores for the two items were then summed. A summed score of 2 would indicate a low level of job stress. A summed score of 14 would indicate a high level. The summated scale score for the attribute "job stress" results in equal-appearing intervals[44:48] ranging from 2 to 14. While it could be argued that these summated scores can be treated as interval-scale data,[44:16,17,28,29] for the purposes of the correlational analyses used in this study, we treated them as being ordinal.

Content validity for the JAS-RCP was established via review by a panel of experts. The use of two or more items to assess specific variables, and the inclusion of selected items that had been used in previous research, provided additional evidence of instrument validity. Following review and revision by the panel, the JAS-RCP was field-tested on a small group of RCPs. Each administration was timed, and the participants were interviewed following their completion of the instrument to ensure that items were clear and easy to understand.

The JAS-RCP was next administered to a pilot-test group of 20 RCPs randomly selected from the staff of a local 700-bed medical center. After an interval of 2 weeks, the measure was repeated to evaluate the test-retest reliability of the items. JAS-RCP Part I test-retest reliability coefficients[44-46] were calculated for each item and each summed score of items used to assess a given attribute. For example, the items used to assess the attribute "nursing respect" were

"The nurses at work respect what I do"

and

"The nursing staff respects my field."

These items had test-retest reliability coefficients of $r = 0.85$ ($p = 0.0003$) and $r = 0.77$ ($p = 0.0002$), respectively. The summed score for these two items had a test-retest reliability coefficient of $r = 0.87$ ($p = 0.0002$). Items that had a poor test-retest reliability were deleted from the final version of the JAS-RCP Part I. Following revision, the remaining items used in the study had test-retest reliability coefficients ranging from $r = 0.49$ ($p = 0.03$) to $r = 1.0$ ($p < 0.001$). A sample of part of the final version of the JAS-RCP Part I can be found in the Appendix.

Part II of the instrument consisted of the Job Descriptive Index (JDI) described by Smith, Kendall, and Hulin.[25] The JDI is composed of five subscales for job satisfaction: the work, pay, promotions, supervision, and co-workers.[25] While Smith et al do not recommend combining the subscales for an estimate of overall JS, doing so is a common practice in the literature. According to Kerr,[41] recommendations against combining the subscales are ignored about as often as they are followed. For our study, the subscales were combined for an overall JS score. This overall score must be interpreted with caution because there is not complete agreement that such combination is appropriate.

The JDI is reported to have a test-retest reliability coefficient between 0.70 and 0.80.[25] It is of interest that the JDI test-retest reliability coefficients for our pilot study ranged from $r = 0.65$ to $r = 0.88$.

Discriminant, convergent, and predictive validity studies have been performed on the JDI, with good results.[25] The JDI subscales were used to determine the job-specific variables of satisfaction with work, salary, promotions, co-workers, and supervision. Each subscale (satisfaction with work, co-workers, and supervision) ranges from a low of 0 to a maximum of 54 points. The pay and promotions subscales range from 0 to 27.

Part III of the instrument consisted of Jones' Staff Burnout Scale for Health Professionals (SBS-HP).[16,19,47] The SBS-HP has a 0.93 Spearman-Brown split-half reliability coefficient.[16] The pilot-study test-retest reliability coefficient for the SBS-HP was $r = 0.95$.

Validity data on the SBS-HP have been reported to be "excellent."[48] Burnout as measured by the SBS-HP reliably correlates with job satisfaction and turnover, absenteeism, alcohol and drug use, occupational mistakes, dishonesty regarding theft

on the job, unauthorized work-break extensions, and physical illness.[16,48] Possible scores on the SBS-HP range from 20 (minimal burnout) to 140 (severe burnout).[16]

Analysis of the Data

The data were analyzed with the CSS (Complete Statistical System) statistical package for microcomputers (StatSoft, Tulsa OK). The following statistical tests were performed:

1. Analysis of variance (ANOVA): Burnout scores for nominal-scale job-related, demographic, and professional variables were compared by ANOVA. The F ratio was then tested to determine whether there were significant differences between burnout scores and different categories of each nominal variable.[49:162-168] Variables analyzed in this fashion were type of organization, location, job status, work setting, professional credential, work-week configuration, shift assignment, gender, and marital status. A significant F test was followed by a post-hoc Student-Newman-Keuls test to compare paired mean burnout scores for a significant difference ($p < 0.05$).[49:190]

2. Correlations: Spearman rank correlations were performed among JAS-RCP Part I rating-scale variables, burnout, and each measure of JS.[49:318-320] Variables analyzed in this fashion were organizational climate, participation in decision making, communication within the organization, organizational stability, frequency of rotation of daily assignments, scheduling flexibility and time off, perception of appropriate work load, recognition by nursing and physicians, role clarity, job freedom, independence and autonomy, control over the job, co-worker and supervisor support, perception of the quality of the department, job stress, social support, and health.

Pearson product moment correlations were performed among interval and ratio-scale data, JS scores, and burnout scores.[42:121-126] Variables analyzed in this fashion were hospital bed-size, size of the respiratory care department (number of employees), salary, hours worked per week, basic-care work load, intensive-care work load, years of experience, years of professional education, years at current job, turnover history (as years per job), and absenteeism.

A significant correlation ($p < 0.05$) would indicate a relationship or association between two variables.[42:327-330]

3. Multiple regression: A forward stepwise multiple regression analysis was performed that included all organizational, job-specific, and personal variables from the foregoing correlations as the independent variables and burnout scores as the dependent variables.[50]

For JS, the regression analysis was repeated, using the organizational, job-specific, and personal variables as the independent variables and each of the JS subscales as the dependent variable.

A coefficient of multiple correlation (multiple R) significance level of $p < 0.05$ would indicate the ability of these organizational, job-specific, and personal variables, when used in combination, to predict burnout or JS.[50] A significant t test of the partial regression coefficients ($p < 0.05$) for each variable in the regression equations would indicate that particular variable's ability to predict burnout or JS after the other variables had already contributed toward the prediction.[50] Multiple R^2 was then reviewed to determine the amount of variance in burnout and JS scores accounted for by the independent variables.[50]

Results

There was no significant difference between the respondents and the telephone-surveyed nonrespondents in burnout level or in JS, as shown here:

Respondents (n = 458):	Mean (SD) burnout score, 59.5 (19.4)
Nonrespondents (n = 33):	Mean (SD) burnout score, 57.5 (16.7)
	t = 0.581 (p = 0.56)
Respondents (n = 444):	Mean (SD) overall JS score, 123.7 (38.4)
Nonrespondents (n = 33):	Mean (SD) overall JS score, 131.8 (38.9)
	t = −1.17 (p = 0.24)

Analysis of Variance and Burnout

Comparisons of mean burnout scores by type of organization, location, individual job status, work setting, credential, work-week configuration, shift

assignment, gender, and marital status are found in Table 1. The mean (SD) burnout score for the entire sample (n = 458) was 59.5 (19.4). Included in Table 1 are the ANOVA F-test results. There were no significant differences ($p < 0.05$) in the burnout scores associated with any of the variables except work-week configuration, which showed a significant difference ($F = 3.64$, $p = 0.0128$).

The post-hoc Student-Newman-Keuls multiple comparison tests for work-week configuration versus burnout indicated that while the differences in burnout levels among those with different work-week configurations were large, no one difference in a specific work-week configuration was statistically significant ($p > 0.05$). The comparisons were between the following work-week configurations.

Five 8-hr shifts and four 10-hr shifts
Five 8-hr shifts and three 12-hour shifts
Five 8-hr shifts and other
Four 10-hr shifts and three 12-hr shifts
Four 10-hr shifts and other
Three 12-hr shifts and other

Correlations for Burnout and Job Satisfaction

Spearman rho and Pearson product moment correlations among organizational factors, job-specific factors, personal variables, burnout, and JS scores are found in Table 2. Organizational variables that were significantly correlated ($p < 0.05$) with burnout and all measures of JS were organizational climate, employee participation in decision-making, communication, and organizational stability. As these factors improved, JS increased and burnout decreased.

Job-specific variables that significantly correlated with burnout and all aspects of JS were scheduling flexibility, ease of obtaining time off, and perception of an appropriate work load. As these job-related factors improved, JS increased and burnout decreased.

Job freedom, autonomy, independence, and control were all negatively correlated with burnout and positively correlated with all aspects of JS. Increased recognition by physicians and nurses as well as increased supervisor and co-worker support

Table 1. Burnout Scores by Subject Variables

Category	n	Burnout Score Mean (SD)	ANOVA F	ANOVA p
Total Sample	458	59.5 (19.4)		
Type of Organization				
Hospital	431	59.9 (19.3)	1.73	0.18
Home care company	11	55.4 (20.3)		
Other	14	50.9 (21.7)		
Location				
Urban	232	60.4 (19.1)	0.47	0.71
Suburban	118	59.9 (19.4)		
Rural	77	57.4 (19.3)		
Other	9	60.3 (22.6)		
Job Status				
Permanent full-time	394	59.6 (19.3)	0.80	0.55
Permanent part-time	32	56.3 (21.6)		
Temporary full-time	5	71.4 (15.2)		
Temporary part-time	10	66.2 (20.3)		
Pool	2	62.0 (9.9)		
Other	6	58.2 (14.6)		
Work Setting				
Basic care	14	54.2 (21.0)	1.8	0.07
Critical care	102	58.6 (17.5)		
Laboratory	14	52.1 (21.5)		
Rotation between basic & critical care	137	62.3 (18.5)		
Rotation in other clinical areas	30	62.0 (19.1)		
Supervisor	63	64.9 (19.8)		
Department manager/ administrator	48	57.1 (20.8)		
Clinical educator/instructor	18	53.7 (23.1)		
Home care	9	53.7 (13.7)		
Credential Held				
RRT	224	58.5 (19.0)	1.31	0.25
CRTT	198	60.8 (19.6)		
CPFT	9	48.2 (23.7)		
RPFT	4	70.3 (13.5)		
RRT/CPFT	11	65.4 (18.0)		
RRT/RPFT	5	50.6 (20.5)		
CRTT/RPFT	4	57.8 (28.6)		
Work-Week Configuration				
Five 8-hr shifts	215	56.5 (18.1)	3.64	0.01
Four 10-hr shifts	11	67.5 (24.2)		
Three 12-hr shifts	66	62.4 (20.9)		
Other	154	61.8 (19.6)		
Shift Assignment				
Days	254	58.0 (19.6)	2.08	0.10
Evenings	71	62.9 (18.4)		
Nights	86	62.2 (18.7)		
Varying	38	56.8 19.4)		
Gender				
Male	191	61.2 (19.2)	2.45	0.11
Female	266	58.3 (19.5)		
Marital Status				
Single	114	62.3 (17.1)	1.15	0.33
Married	287	58.0 (19.7)		
Divorced	48	60.3 (21.9)		
Separated	6	62.0 (20.9)		
Other	2	66.0 (7.1)		

Table 2. Organizational Factors, Job–Specific Factors, and Personal Variables Significantly Correlated with Burnout and All Aspects of Job Satisfaction

Independent Variable	Aspects of Job Satisfaction						
	Work	Pay	Promotions	Supervision	Co–Workers	Overall	Burnout
Organizational Factors*							
Organizational climate	0.54†	0.36	0.43	0.45	0.51	0.64	–0.50
Employee participation in decision making	0.49	0.33	0.41	0.38	0.26	0.50	–0.35
Organizational communications	0.51	0.30	0.47	0.47	0.41	0.60	–0.45
Organizational stability	0.44	0.29	0.36	0.33	0.36	0.49	–0.37
Job-Specific Factors*							
Scheduling flexibility	0.28	0.19	0.23	0.24	0.21	0.33	–0.25
Ease of obtaining time off	0.32	0.29	0.28	0.37	0.27	0.44	–0.33
Perception of work load	0.33	0.30	0.25	0.32	0.29	0.43	–0.30
Freedom	0.50	0.32	0.33	0.38	0.31	0.51	–0.37
Autonomy	0.38	0.23	0.25	0.29	0.25	0.38	–0.27
Job control	0.57	0.28	0.42	0.42	0.31	0.55	–0.46
Job independence	0.52	0.33	0.38	0.41	0.27	0.51	–0.33
Recognition by physicians	0.51	0.24	0.25	0.21	0.30	0.40	–0.37
Recognition by nursing	0.51	0.27	0.34	0.27	0.35	0.47	–0.44
Role clarity	0.35	0.22	0.37	0.57	0.30	0.51	–0.40
Quality of department	0.55	0.30	0.44	0.48	0.44	0.63	–0.41
Job stress	–0.26	–0.15‡	–0.24	–0.18	0.19	–0.28	0.44
Supervisor support	0.40	0.27	0.37	0.72	0.29	0.60	–0.36
Co-worker support	0.43	0.27	0.33	0.39	0.62	0.60	–0.36
Personal Variables							
Family support*	0.19	0.20	0.10§	0.12§	0.16	0.20	–0.28
Social support (friends)*	0.27	0.16	0.12‡	0.16	0.20	0.26	–0.34
Burnout¶	–0.59	–0.30	–0.41	–0.36	–0.41§	–0.5	—
Outcome Variables*							
Intent to leave job	–0.50	–0.26	–0.43	–0.33	–0.31	–0.49	0.49
Intent to leave field	–0.55	–0.32	–0.45	–0.30	–0.29	–0.52	0.51

* Spearman rank correlations are reported for JAS-RCP Part I rating-scale variables vs burnout & job satisfaction.

† $p < 0.01$ for all values not otherwise marked.

‡ $p < 0.01$.

§ $p < 0.05$.

¶ Pearson product moment correlations are reported for the variables burnout vs job satisfaction.

were also associated with improved JS and declines in burnout. As role clarity improved and job stress declined, there was a decline in burnout and an increase in all measures of JS. As all measures of JS increased, burnout level decreased.

Personal variables associated with burnout and all aspects of JS were family and social support. As these factors improved, burnout level declined and JS level increased.

Table 2 also lists the correlations between intent to leave the job and burnout, and intent to leave the field and burnout. Increased burnout levels and decreased JS levels were associated with increased intent to leave the job and the field.

Predictors of Burnout

A significant coefficient of multiple correlation ($R = 0.78$, $R^2 = 0.61$, $p < 0.0001$) indicated that in

combination, all organizational, job-specific, and personal variables accounted for 61% of the variance observed in burnout scores (Table 3). The strongest predictor of burnout level was the job-stress level. Other job-related variables able to add significantly to the prediction of burnout level were size of the department, satisfaction with work, satisfaction with co-workers and co-worker support, job independence and control, recognition by nursing, and role clarity.

Personal variables that were strong predictors of burnout level were age, number of jobs held in the past, social support, and intent to leave the field of respiratory care (Table 3).

Table 3. The Ability of Organizational Factors, Job-Related Factors, and Personal Variables To Predict Level of Burnout (Forward Stepwise Multiple Regression Analysis*)

	Regression Weights for Significant Organizational, Job-Specific, & Personal Predictors of Burnout			
Variable	Beta†	b‡	t	p Value
Organizational & Job–Related Factors				
Job stress	0.23	1.5	6.18	< 0.00001
Size of department (no. of employees)	–0.15	–0.11	3.99	0.00008
Satisfaction with work	–0.18	–0.31	–3.39	0.00078
Satisfaction with co-workers	–0.13	–0.18	–2.8	0.00539
Control	–0.15	–0.84	–2.6	0.01130
Co-worker support	0.13	0.80	2.5	0.01365
Independence	0.12	0.71	2.2	0.02692
Recognition by nursing	–0.09	–0.56	–2.1	0.03456
Role clarity	–0.09	–0.29	–2.1	0.04163
Personal, Professional, & Demographic Variables				
Age	–0.17	–0.45	–4.2	0.00004
No. of different jobs held	0.12	0.74	3.1	0.00205
Social support	–0.10	–0.87	–2.49	0.01339
Intent to leave the field	0.12	0.57	2.1	0.03365

* Dependent variable burnout. Independent variables: organization factors, job-related factors, and personal variables. No. of cases: 374. No. of steps: 26. Multiple R = 0.78; multiple R^2 = 0.61. F (26, 347) = 21.0 ($p < 0.0001$). Intercept: 91.0.

† Beta: standardized partial regression coefficients.

‡ Partial regression coefficients.

Predictors of Job Satisfaction

Tables 4-8 show that significant coefficients of multiple correlation indicated that, in combination, the organizational, job-specific, and personal variables accounted for 63% of the variance in satisfaction with the work, 36% of the variance in satisfaction with pay, 36% of the variance in satisfaction with promotions, 62% of the variance in satisfaction with supervision, and 48% of the variance in satisfaction with co-workers. Statistical significance is shown in the tables.

Table 4. The Ability of Organizational Factors, Job-Related Factors, and Personal, Professional, and Demographic Variables To Predict Job Satisfaction When the Dependent Variable Is Satisfaction with Work (Forward Stepwise Multiple Regression Analysis*)

	Regression Weights for Significant Variables			
Variable	Beta†	b‡	t	p Value
Organizational & Job-Related Factors				
Recognition by physicians	0.15	0.54	3.30	0.00105
Recognition by nursing	0.13	0.45	2.83	0.00499
Personal, Professional, & Demographic Variables				
Burnout	–0.22	–0.13	–4.90	< 0.00001
Intent to leave field	–0.22	–0.62	–4.29	0.00002
Absenteeism (illness)	0.09	0.34	2.31	0.02105
Age	–0.08	–0.12	–2.20	0.02880

* Dependent variable: satisfaction with work. Independent variables: organizational, job-related, and personal variables. No. of cases for all variables: 374. No. of steps: 18. Multiple R = 0.79; multiple R^2 = 0.63. F (18, 355) = 33.6 ($p < 0.0001$). Intercept: 19.9.

† Beta: standardized partial regression coefficients.

‡ Partial regression coefficients.

The strongest job-related predictors of level of satisfaction with the work were recognition by physicians and by nursing (Table 4). Personal and professional variables that were good predictors of work-satisfaction level were age, burnout level, absenteeism, and intent to leave the field.

The strongest job-related predictor of level of satisfaction with pay was actual salary received (Table 5). Personal and professional variables that were good predictors of level of satisfaction with

Table 5. The Ability of Organizational Factors, Job-Specific Factors, and Personal, Professional, and Demographic Variables To Predict Job Satisfaction When the Dependent Variable Is Satisfaction with Pay (Forward Stepwise Multiple Regression Analysis*)

Variable	Regression Weights for Significant Variables			
	Beta†	b‡	t	p Value
Organizational Factors				
Salary	0.24	0.32	5.23	< 0.00001
Independence	0.25	0.52	3.24	0.00132
Organizational climate	0.20	0.25	3.19	0.00154
Ease of obtaining time off	0.15	0.28	2.97	0.00316
Job stress standardized	–0.10	–0.23	–2.07	0.03957
Personal, Professional, & Demographic Variables				
Intent to leave field	–0.20	–0.35	–2.93	0.00364
No. of dependent children	0.12	–0.81	–2.52	0.01213
Absenteeism	0.11	0.33	2.41	0.01635

* Dependent variable: satisfaction with pay. Independent variables: organizational, job-related, and personal variables. No of cases: 374. No of steps: 21. Multiple R = 0.60; multiple R^2 = 0.36. F (21, 352) = 9.31 ($p < 0.0001$). Intercept: 2.01.

† Beta: standardized partial regression coefficients.

‡ Partial regression coefficients.

pay were level of absenteeism, intent to leave the field, and the number of dependent children.

The significant organizational and job-related predictors of level of satisfaction with promotions were recognition by nursing, participation in decision making, and job stress (Table 6). Personal and professional variables that were good predictors of level of satisfaction with promotions were intent to leave the field, past turnover rates, and absenteeism (Table 6).

The strongest job-related predictors of level of satisfaction with supervision were supervisor support, role clarity, independence, and ease of obtaining time off (Table 7). The best predictor of level of satisfaction with co-workers was co-worker support (Table 8).

Discussion

Before we discuss the study findings' meanings, it is important to acknowledge the limitations of the study design. Correlational designs are concerned with determining the extent of relationships existing between variables.[42] The presence of a significant correlation between variables does not in itself imply cause and effect. Further, descriptive research that uses self-report questionnaires depends for its degree of validity on the acccuracy of reporting by participants, which is not wholly controllable by the researchers. It is also important to acknowledge that responses are based on respondents' perceptions about work. For example, a respondent reporting a low level of job control may work side by side with a person who reports a high level of job control, although both have the same physical work environment.

There are clearly significant relationships between organizational, job-specific, demographic, personal, and professional variables on the one hand—and job satisfaction and burnout on the other hand. Table 9 summarizes what we found to

Table 6. The Ability of Organizational Factors, Job-Specific Factors, and Personal, Professional, and Demographic Variables To Predict Job Satisfaction When the Dependent Variable Is Satisfaction with Promotions (Forward Stepwise Multiple Regression Analysis*)

Variable	Regression Weights for Significant Variables			
	Beta†	b‡	t	p Value
Organizational & Job-Specific Factors				
Recognition by nursing	0.12	0.28	2.46	0.01421
Employee participation in decision making	0.14	0.28	2.39	0.01721
Job stress	–0.12	–0.29	–2.39	0.01738
Personal, Professional, & Demographic Variables				
Intent to leave field	–0.21	–0.39	–4.17	0.00004
Past turnover (yrs/job in the field)	–0.10	–0.24	–2.06	0.03974
Absenteeism (illness)	0.09	0.23	2.05	0.04085

* Dependent variable: satisfaction with promotions. Independent variables: organizational, job-related, and personal variables. No. of cases: 374. No. of steps: 15. Multiple R = 0.60; multiple R^2 = 0.36. F (15, 358) = 13.3 ($p < 0.0001$). Intercept: 7.28.

† Beta: standardized partial regression coefficients.

‡ Partial regression coefficients.

Table 7. The Ability of Organizational Factors, Job-Related Factors, and Personal, Professional, and Demographic Factors To Predict Job Satisfaction When the Dependent Variable Is Satisfaction with Supervision (Forward Stepwise Multiple Regression Analysis*)

Variable	Regression Weights for Significant Variables			
	Beta†	b‡	t	p Value
Organizational & Job-Related Factors				
Supervisor support	0.64	2.52	13.40	< 0.00001
Role clarity	0.14	0.34	3.21	0.00141
Independence	0.12	0.51	2.43	0.01579
Ease of obtaining time off	0.09	0.34	2.36	0.01861
Personal, Professional, & Demographic Factors				
No. of dependent children	0.07	1.02	2.16	0.03145
Absenteeism (for reasons other than illness)	–0.07	–0.44	–2.09	0.03692
Intent to leave field	–0.08	–0.26	–2.09	0.03754

* Dependent variable: satisfaction with supervision. Independent variables: organizational, job-related, and personal variables. No. of cases: 374. No. of steps: 11. Multiple R = 0.79; multiple $R^2 = 0.62$. F (11, 362) = 54.5 ($p < 0.0001$). Intercept: 3.13.

† Beta: standardized partial regression coefficients.

‡ Partial regression coefficients.

be the significant predictors of JS and burnout, based on the regression analyses. For example, organizational climate and participation in decision making were good predictors of the level of satisfaction with pay and promotions. As might be expected, the ease of obtaining time off could predict levels of satisfaction with supervision and pay. The best predictors of the level of satisfaction with the work were professional recognition by physicians and nursing. Role clarity was related to the level of satisfaction with supervision and to the level of burnout. The level of job stress was associated with the levels of satisfaction with pay, satisfaction with promotions, and burnout.

It is of interest that levels of burnout and all aspects of JS, except satisfaction with co-workers, were strong predictors of intent to leave the field. There also was a relationship between all aspects of JS and absenteeism.

Burnout

The single best predictor of burnout level was job-stress level. Decreased JS, poor role clarity, and a lack of job control and job independence were also strongly associated with increased levels of burnout. As burnout level increased, so did measures of turnover and intent to leave the field. We believe that these findings support the notion that burnout among RCPs is caused by excessive job stress and that high levels of staff burnout may result in increased departures from the field. Steps that respiratory care managers can take that may reduce burnout levels among RCPs include actions to reduce job stress, improve employees' understanding of their roles, and increase workers' control over their jobs.

It is of interest that a lack of recognition by nursing was a good predictor of level of burnout. While a lack of professional recognition can lead to increased job stress, job dissatisfaction, and in-

Table 8. The Ability of Organizational Factors, Job-Specific Factors, and Personal, Professional, and Demographic Variables To Predict Job Satisfaction When the Dependent Variable Is Satisfaction with Co-Workers (Forward Stepwise Multiple Regression Analysis*)

Variable	Regression Weights for Significant Variables			
	Beta†	b‡	t	p Value
Organizational & Job-Related Factors				
Co-worker support	0.49	2.3	9.65	< 0.00001
Quality of department	0.16	0.65	2.49	0.01312
Supervisor support	–0.11	–0.45	2.18	0.02999
Personal, Professional, & Demographic Variables				
Burnout	–0.21	–0.15	–4.04	0.00007
Total absenteeism	0.12	0.39	2.91	0.00384
No. of different jobs held	–0.09	-0.38	–2.16	0.03164
No. of dependent children	–0.08	–1.1	–2.04	0.04212

* Dependent variable: satisfaction with co-workers. Independent variables: organizational, job-related, and personal variables. No. of cases: 374. No. of steps: 17. Multiple R = 0.69; multiple $R^2 = 0.48$. F (17, 356) = 19.5 ($p < 0.0001$). Intercept: 17.2.

† Beta: standardized partial regression coefficients.

‡ Partial regression coefficients.

Table 9. Significant Organizational, Job-Related, and Personal Predictors of Job Satisfaction and Burnout (Based on Regression Analysis)

	Aspect of Job Satisfaction					
Variables	Work	Pay	Promotions	Supervision	Co-Workers	Burnout
Organizational Factors						
Organizational climate	—	X	—	—	—	—
Employee participation in decision making	—	—	X	—	—	—
Job-Specific Factors						
Ease of obtaining time off	—	X	—	X	—	—
Job independence	—	X	—	X	—	X
Job control	—	—	—	—	—	X
Recognition by physicians	X	—	—	—	—	—
Recognition by nursing	X	—	X	—	—	X
Role clarity	—	—	—	X	—	X
Job stress	—	X	X	—	—	X
Salary	—	X	—	—	—	—
Quality of department	—	—	—	—	X	—
Supervisor support	—	—	—	X	X	—
Co-worker support	—	—	—	—	X	X
Department size	—	—	—	—	—	X
Personal Variables						
Age	X	—	—	—	—	X
No. of children	—	X	—	X	X	—
No. of different jobs/ past turnover	—	—	X	—	X	X
Social support	—	—	—	—	—	X
Absenteeism	X	X	X	X	X	—
Intent to leave field	X	X	X	X	—	X

creased turnover.[39] RCPs may dispute the importance of recognition by nursing. This study found that, while recognition by physicians was correlated with lower levels of burnout, a lack of recognition by nursing was a better predictor of the level of burnout. This would seem to reflect the fact that the typical RCP spends a good deal more time on the job interacting with nursing personnel than with physicians.

There were no clear differences in burnout levels associated with a specific work environment. Organizational and job-specific factors that had no relationship with burnout were type of organization (hospital, clinic, home care), location of the workplace (urban, suburban, rural), job status (part time, full time, temporary, permanent, pool), work setting (intensive care, basic care, pulmonary laboratory, supervision), or shift assignment.

Other organizational and job-specific variables not related to burnout in this study were hospital size, number of hours worked per week, and variety of procedures performed. Higher salaries were not associated with lower burnout levels. There was no clear relationship between actual patient care work load and burnout level.

Of the personal variables, the strongest predictors of burnout level were age, number of jobs held, social support, and intent to leave the field. As social support improved, burnout level declined. Burnout also declined with increasing age. This is consistent with the findings of others.[1,51,52] The reasons for the decline in burnout levels found in older health-care professionals are not as clear. It may be that those who suffer severe burnout leave the field at an early stage in their careers. Those with lower levels of burnout tend to stay on the job and in the field. As expected, burnout level declined as family support increased.

Key personal variables that had no relationship to burnout level were years of professional educa-

tion, professional credential held, gender, and marital status. Higher levels of credential or education were not associated with lower levels of burnout.

Job Satisfaction

The best predictors of satisfaction with the work were recognition by physicians and nursing. It is difficult to speculate whether a cause-and-effect relationship may be involved. It is possible that the motivated and effective RCP with a high level of work satisfaction and low level of burnout also experiences a high level of professional recognition. RCPs who are dissatisfied with the work seem to experience an increased level of burnout and higher absenteeism—and are more likely to leave the field.

The best single predictor of level of satisfaction with pay was actual salary. Those who are more highly paid tend to be more satisfied. It would also seem that a flexible schedule with easy availability of time off can improve satisfaction with pay. A high-stress work environment may reduce satisfaction with pay. A large number of children to support may tend to reduce satisfaction with salary. Older workers seem to be more satisfied with their pay than younger workers, and this may be due to the incremental increases in salary often associated with staying on the job longer.

Key factors associated with level of satisfaction with promotions were increased professional recognition and participation in decision making. Increased job stress, a higher past turnover rate, a higher rate of absenteeism, and a greater intent to leave the field were all associated with dissatisfaction with promotions. Dissatisfaction with the outlook for advancement on the job seems to increase the probability of turnover. Managers who wish to improve job satisfaction in this regard might consider implementing a career-ladder system.

The level of satisfaction with supervision was associated with ease of obtaining time off, employee's independence on the job, role clarity, and supervisor support. Supervisors who want to maximize JS may wish to take note. Also, as might be expected, the best predictor of satisfaction with co-workers was co-worker support. Improved satisfaction with supervisors and co-workers may reduce absenteeism and turnover.

Factors that were not associated with JS were frequency of rotation of job assignments, actual basic-care work load, and hospital size. There was a very weak but significant correlation between an increasing variety of tasks performed and satisfaction with work ($r = 0.15$, $p = 0.001$). This is consistent with the findings of Hmelo and Axton.[8]

Conclusions

In our study, reduced job stress, increased job independence and job control, improved role clarity, and high levels of job satisfaction were all associated with lower levels of professional burnout. A lack of job satisfaction and higher levels of burnout were associated with an increase in intent to leave the job and the field. These findings are consistent with the literature. We also found that older workers and those with strong support networks tended to have lower levels of burnout. While correlation does not imply causation, we believe that our findings have implications for respiratory care service managers. Attention to those factors associated with reduced job stress, improved job satisfaction, and lower levels of professional burnout may improve patient care and reduce absenteeism and turnover among respiratory care practitioners.

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(Appendix appears on next page.)

APPENDIX

A Sample Page from the Survey

Georgia State University
Job Analysis Survey
for
Respiratory Care Practitioners

Part 1

INSTRUCTIONS

FOR EACH STATEMENT BELOW INDICATE WHICH BEST REFLECTS YOUR CURRENT STATUS IN THE FIELD OF RESPIRATORY CARE

---

1. My current age is _____ years.

2. I am ( ) male ( ) female.

3. My marital status is ( ) single ( ) married ( ) divorced ( ) separated ( ) other: _____.

4. I have_____ years of experience in respiratory care (includes PFTs, ABGs, etc) (example: 5 years).

5. I have been employed at my current job for about _____ years.

6. The highest level of education I have completed in respiratory care is
   ( ) on the job training ( ) an Associate Degree Therapist program
   ( ) a Respiratory Technician training program ( ) a Baccalaurate Therapist program
   ( ) other (please write in): _____.

7. My salary is about _____ dollars per hour (example: $10.50).

   If you prefer, list salary as dollars per year: _____ (example: $25,700 per year).

8. I have worked a total of _____ in different hospitals or health care agencies in the field of respiratory care during my career (example: 5 jobs).

9. My primary place of employment is a ( ) hospital ( ) clinic ( ) home care company
   ( ) other (please fill in): _____.

10. If the primary place of employment is a hospital, please list the approximate bed size: _____.
    (example: 200 beds)

Bronchodilating Efficacy of an Open-Spacer Device Compared to Three Other Spacers

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BACKGROUND: Spacers devices are commonly used in aerosol therapy; however, they are bulky and require regular cleaning. A compact open spacer (OS, Synchroner, Fisons, UK) has been developed to overcome this problem. We compared bronchodilator efficacy associated with its use to efficacy of same dose via three other spacers: Volumatic (Glaxo Laboratories), Nebuhaler (Astra Laboratories), Inspirease (Key Pharmaceuticals). MATERIALS & METHODS: Sixteen asthmatics (> 20% reversibility of FEV_1) took part in the study. In random order, they used a different device on each of the 4 study days to inhale 2 puffs of a combination aerosol (1 mg reproterol and 2 mg sodium cromoglycate, Aarane). We recorded results of spirometry before and 5, 30, and 60 minutes after bronchodilator inhalation. RESULTS: At each time, we found no significant difference in bronchodilation. CONCLUSION: OS is as efficient as other commonly used spacers to produce bronchodilation resulting from a conventional dose of reproterol. (Respir Care 1992;37:61-64.)

Background

Spacer devices have been introduced for use in conjunction with metered dose inhalers (MDI) to improve the efficacy of this medication delivery system.[1,2] Spacers have several benefits: they slow the aerosol jet; they enhance vaporisation of propellant to achieve small particles; they eliminate the need to coordinate actuation and inhalation; and they decrease oropharyngeal deposition of aerosol particles.[3]

A number of spacer devices of differing designs, (such as straight-tube spacers, rigid or collapsible plastic reservoirs, and chambers with one-way valves[4-7]) have been developed in the USA and in Europe; however, they are bulky and need regular cleaning. A compact open spacer (OS, Synchroner, Fisons, UK) has been developed to overcome this problem (Fig. 1): a 10-cm cylinder with an opening in its upper surface. This device shares the advantages of other spacers except that it requires good coordination of actuation with inhalation by the patient. However, if the inspiratory maneuver is mistimed, the open-tube design permits the patient to see the aerosol cloud generated by activation, indicating faulty inhalation technique (Fig. 2). In a 1982 abstract, Newman et al[8] showed that in normal volunteers under experimental, but not clinical, conditions the OS delivers more drug to the periphery of the lung than a conventional well-actuated MDI and also decreases the oropharyngeal deposition of the drug. The objective of our study was to determine whether the OS was as efficient in terms of bronchodilation as other commonly used spacers.

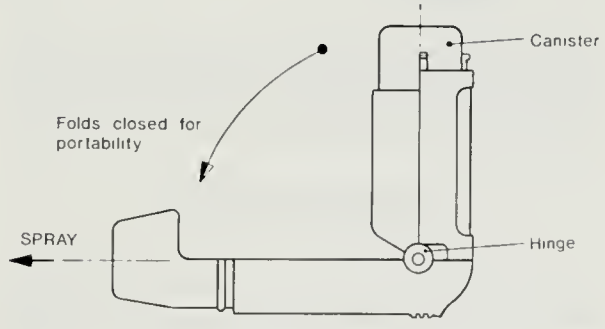

Fig. 1. Diagrammatic representation of the open spacer.

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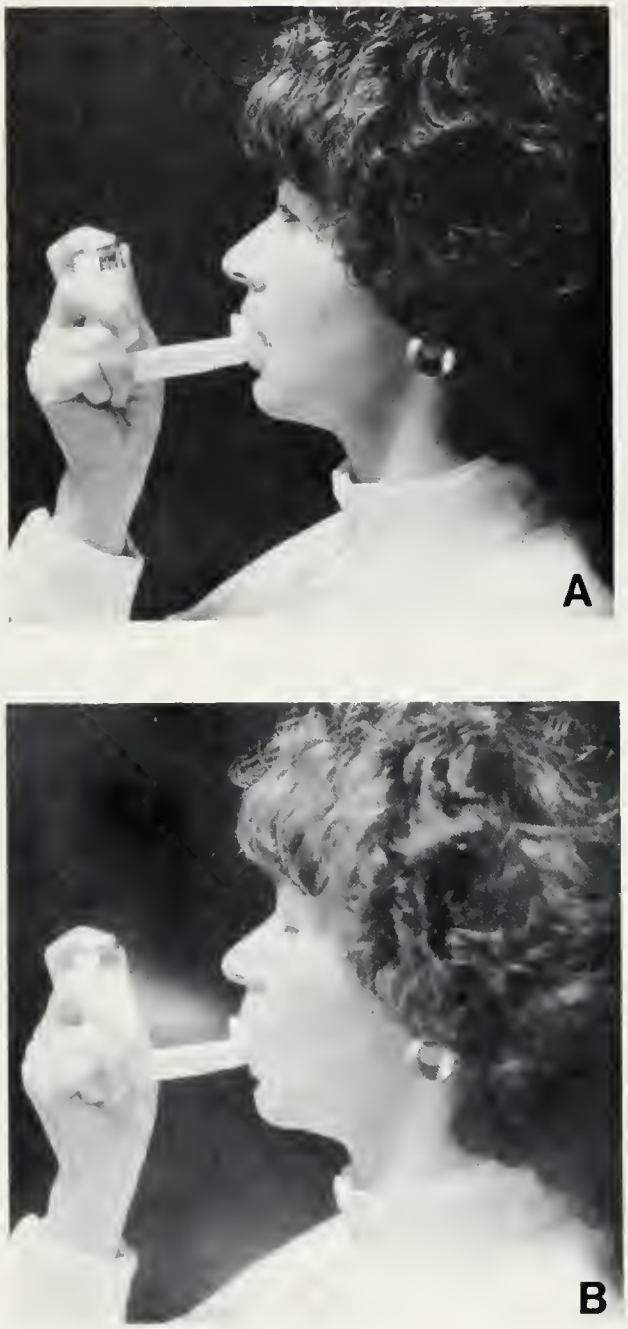

Fig. 2. Actuation of the MDI with open spacer with good (A) and poor (B) coordination. The patient sees the generated cloud of drug particles (B) only when coordination of actuation and inhalation is inadequate. (Used with permission.)

Methods and Materials

Because clinical practice differs from experimental conditions, we studied a group of asthmatic patients under normal hospital conditions to assess not only efficiency but clinical acceptability of the OS. We used a conventional dosage of beta-agonist bronchodilator (reproterol).

The study was approved by the ethics committee of the University of Geneva, and informed consent was obtained from the patients. We studied a convenience sample of 16 moderately asthmatic patients (12 men, 4 women) aged 30-63 years (mean 45 years) who had been in stable clinical condition for at least 14 days. Oral and inhaled bronchodilators were withheld for at least 12 hours and theophyllines for at least 24 hours prior to each study day. All patients demonstrated an FEV_1 reversibility > 20% after inhalation of a single dose of albuterol (200 μg). The patients were then taught how to use the MDI using each of the four spacer devices (Fig. 3). They were allowed to practice as much as necessary using a placebo MDI until they all used the devices correctly. The four spacers used were Volumatic (VO, Glaxo Laboratories, UK), Nebuhaler (NE, Astra Laboratories, Sweden), Inspirease (IN, Key Pharmaceuticals, USA), and OS (Fisons, UK). On each of the 4 study days, spirometry (via Gould 2400, Dayton, Ohio, USA) was measured at the same time each morning 5 minutes before and 5, 30, and 60 minutes after the administration of 2 puffs of a combination aerosol containing 4 mg sodium cromoglycate and 2 mg reproterol (Aarane, Fisons plc, UK) using one of the four inhalation devices. The order in which the 4 devices were used was randomised using a Latin square design, with each patient using a different spacer on each of the 4 days. The results were statistically analysed using a 2-way analysis of variance and are expressed as mean with standard deviation (SD).

Fig. 3. The four spacers studied—Top left: Volumatic. Top right: Nebuhaler. Bottom left: Inspirease. Bottom right: the open spacer closed and open.

Table 1. Lung Function Measurements before and after Two Puffs of Reproterol—Sodium Cromoglycate

Parameter/ Change at	VO* mean (SD)	NE mean (SD)	IN mean (SD)	OS mean (SD)	F Value	p Value
FEV_1						
Baseline	2.0 (1.09)	2.01 (1.15)	2.10 (1.19)	2.21 (1.05)	2.4	0.07
5 min	0.35 (0.28)	0.42 (0.33)	0.46 (0.29)	0.31 (0.53)	1.1	0.37
30 min	0.51 (0.38)	0.59 (0.41)	0.63 (0.36)	0.45 (0.49)	1.7	0.18
60 min	0.58 (0.41)	0.65 (0.44)	0.71 (0.38)	0.50 (0.46)	2.0	0.13
FVC						
Baseline	3.22 (1.46)	3.29 (1.56)	3.15 (1.47)	3.41 (1.38)	2.1	0.12
5 min	0.34 (0.38)	0.33 (0.37)	0.47 (0.44)	0.35 (0.36)	0.8	0.49
30min	0.56 (0.45)	0.50 (0.41)	0.65 (0.51)	0.47 (0.39)	1.2	0.31
60 min	0.62 (0.56)	0.58 (0.44)	0.72 (0.55)	0.47 (0.41)	1.4	0.25
FEF_{50}						
Baseline	1.77 (1.51)	1.68 (1.42)	1.72 (1.53)	2.06 (1.41)	1.4	0.27
5 min	0.33 (0.39)	0.55 (0.50)	0.49 (0.45)	0.11 (0.25)	1.4	0.27
30 min	0.56 (0.57)	0.77 (0.67)	0.71 (0.57)	0.36 (0.24)	1.4	0.27
60 min	0.55 (0.48)	0.75 (0.64)	0.76 (0.52)	0.37 (0.17)	1.5	0.23
PEFR (L/min)						
Baseline	346 (154)	364 (170)	349 (162)	396 (160)	5.2	0.01
5 min	73 (66)	68 (74)	78 (54)	52 (82)	1.3	0.29
30 min	108 (77)	97 (85)	106 (57)	61 (86)	3.1	0.03
60 min	134 (91)	120 (90)	110 (68)	69 (77)	4.0	0.01

*VO = Volumatic, NE = Nebuhaler, IN = Inspirease, OS = open spacer.

Results

The time course of action of reproterol is shown in Table 1 for each of the measured parameters. There is an increase in bronchodilation for each parameter with a plateau between 30 and 60 minutes (ie, no significant difference in FEV_1 at 60 vs 30 min) (Fig. 4). Between the 4 spacer devices, no significant differences could be demonstrated at any time with any parameter except with PEFR. OS produced a very small but significantly higher increase in PEFR at 30 and 60 minutes than the other spacers. However, the baseline PEFR values with OS were also significantly higher than with the other tested devices.

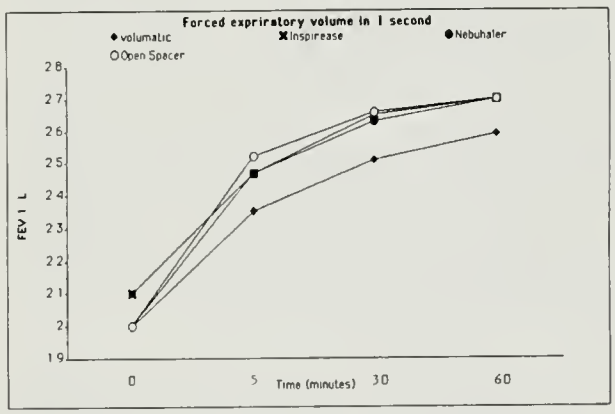

Fig. 4. FEV_1 change after 2 puffs of reproterol/sodium cromoglycate using the four spacer devices. The difference between FEV_1 at 30 and 60 minutes is statistically nonsignificant and, thus, effect is said to plateau.

Discussion

Reproterol plus sodium cromoglycate given by metered dose aerosol at the dose we used is a well-accepted and frequently prescribed bronchodilator therapy in Europe. Our study shows that an open-spacer device is as efficient as other commonly used closed chambers to produce bronchodilation in asthmatic patients. Although our device is not a closed chamber, no more loss of drug appears to occur in delivery to the lung than with the other three devices. In their abstract,[8] Newman et al re-ported that with a radiotracer method only 5% of the drug is shown to be lost from the open part of the spacer and that deposition to the oropharynx is decreased in comparison to MDI alone.

It has been shown that holding an MDI several centimeters from the open mouth produces more bronchodilation than actuation into the closed mouth;[9,10] however, other studies have not found this to be beneficial because many patients miss their mouth with this technique.[11,12] In our study, the three other closed spacers produced no additional benefit in comparison with the open spacer. It is possible that our patients were well taught to use the different devices and were not representative of the usual patients encountered in clinical practice. However, Schöni and Robinson,[13] using the same protocol, demonstrated similar results in children, which suggests that coordination is not a real problem when using an OS. As mentioned earlier, the open-tube design allows the patient to see the cloud of aerosolised drug if coordination is inadequate (Fig. 2).

Spacers are usually not collapsible and are less portable than an MDI alone. The open-spacer device can be folded onto the canister of the MDI (Fig. 3) and can be attached to any canister MDI providing a similar valve system. It may be more acceptable and convenient for patients and thus improve compliance with aerosol therapy. Because of the decreased oropharyngeal deposition, this type of device could also be used to dispense inhaled corticosteroids[14] and to prevent the possible side effect of oral candidiasis.

De Blaquiére et al[15] have shown that 62% of patients with chronic lung disease are incorrect users of MDIs, suggesting that even now, most patients do not master the technique of MDI inhalation therapy. Our open-spacer device with its visual feedback may improve inhalation technique and make life simpler for the user.

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The Future Educational Needs of Respiratory Care Practitioners: A Delphi Study

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Introduction

It should not be surprising to anyone familiar with allied health education that a health-care discipline as dynamic and relatively young as respiratory care still faces some unresolved questions related to professional education and credentialing.

From the inception of the respiratory care profession, the accrediting and credentialing agencies and the professional organization have been concerned with entry-level and advanced-level competencies of respiratory care practitioners, their educational preparation, and credentialing. Some important changes in respiratory care clinical practice, education, and credentialing have been documented since the early 1960s. The accreditation standards for respiratory care educational programs were initially adopted by the American Medical Association in 1962 and revised in 1967, 1972, 1977, and 1986. These standards have specified a minimum duration for curriculum of 12 months (1962), 18 months (1967), and 10 months (1972) for technicians, and 20 (1972) for therapists; whereas, the 1986 "Essentials and Guidelines of an Accredited Educational Program for the Respiratory Therapy Technician and the Respiratory Therapist" do not specify any minimum curriculum duration.[1,2]

As early as 1973 and again in 1978, the American Association for Respiratory Therapy (AART) delineated the roles and functions of respiratory care practitioners.[3-5] In 1981, the AART[6] and some department managers favored 2-year entry-level education,[7] and in 1982 the AART solicited the opinions of the membership on 2-year education for entry-level.[8] In 1985, the AART Task Force on Professional Direction began to describe an increased scope of practice with the advent of cross-utilization of respiratory care personnel;[9] and in 1988 and 1989 the Education Committee of the American Association for Respiratory Care (AARC) conceived and conducted this Delphi study to project future educational needs for res-

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The authors and Morris Brown MD, Medical Advisor, and Craig Scanlon EdD RRT, Consultant, constituted the AARC Education Committee in 1988-1989 when the study was performed.

piratory care practitioners. The methodology of this study was reviewed and approved by the 1988 Board of Directors of the AARC and funded by the Association in 1989.

The purposes of this study were to describe the characteristics, traits, and attributes that would be needed by entry-level and advanced-level respiratory care practitioners and to determine the duration of traditional educational preparation that would be necessary to acquire the necessary knowledge and achieve those skills and attributes.

Current interest in the future educational needs of respiratory care practitioners is linked to concern over relatively low pass rates on National Board for Respiratory Care (NBRC) credentialing examinations from 1983 to 1988,[10] an increased emphasis on outcomes and educational program accountability in the 1986 Essentials and Guidelines,[2] changes in the clinical responsibilities of respiratory care practitioners,[9] and projections for the health-care delivery system.

Although no single study can reasonably be expected to answer all of the many complex questions about how to best educate future respiratory care practitioners, knowledge of the future educational needs of respiratory care practitioners may add valuable information to the existing knowledge base upon which professional leaders, curriculum planners, educators, and licensing boards base decisions and formulate policy.

The Delphi methodology was chosen as the best means for predicting the future preparation necessary for education for the respiratory care profession. Because the purpose of this study was futuristic in nature, the committee considered but did not adopt other 'futures' methodologies including trend analysis, multiple-scenario analysis, and cross-impact analysis.

Review of the Delphi Literature

The Delphi technique has allowed researchers to perform studies that assist with answering questions related to technologic and social change as well as future development. Originally developed by the Rand Corporation in 1953,[11] the technique is a method for systematic solicitation and aggregation of informed judgments on key questions and issues from a group of experts. Several characteristics distinguish the Delphi technique from survey research or other group decision-making processes: the use of carefully designed sequential questionnaires, anonymity, iteration with controlled feedback, statistical analysis of group response, multiple interactions attempting to produce consensus of opinion, and expert input.[10-15]

Dalkey and Helmer initially developed the Delphi technique for military use.[16] With a group of seven experts, strategic atomic weapons forecasts and strategies were identified. The Delphi technique has also been applied to patient care issues and has assisted with mapping educational trends, conducting long-range educational planning, developing curriculum, setting organizational goals and educational reforms, and forecasting.[17-20]

Table 1 summarizes applications of the Delphi technique found in the literature related to medicine and health care.[21-43]

The Delphi method evolved in response to the limitations of traditional methods for engaging a specific group's opinions to determine policy and applying expert judgment for determination of future direction.[44] Dalkey and Helmer asserted that using this technique with experts meant confident long-range planning could be pursued.[16]

The validity and reliability of the method are related to its characteristics.[14] First, the use of appropriate experts is central to validity. Dalkey and Helmer[16] advocate the use of experts rather than a random sample of panelists representative of the population. The term expert reflects possession of information and knowledge required to assure selection of needed items, determination of their relevance and importance, and application of their insight to the formation of a considered judgment.[11]

The second characteristic is related to anonymity. With the Delphi method, individual responses are not matched to the identity of the respondent.[14] This approach provides each participant an equal opportunity to present views without the face-to-face confrontations present with other group processes. Each response is given equal importance in the final analysis. The Delphi technique is considered valid because the nature and content of the study is dictated by the expert panelists.[13]

Third, the Delphi sequence includes iteration with controlled feedback. In successive rounds, participants can retain or change their opinion or agree or disagree with other participants. The fore-

Table 1. Applications of the Delphi Technique to Problems Related to Health Care

Specialty	Subject Studied	Numbers of		Random	Subgroups	Reference
		Panelists	Rounds	Sampling		
Patient care	Mortality predictions	19	2	No	No	21
Patient care	Estimations of day surgeries	11	3	No	No	22
Patient care	Elderly dental care policy and direction of care	20	2	Yes	Yes, 3	23
Nursing care	Patient evaluation criteria	662	2	Yes	No	24
Patient care	Barriers to care indicators	12	3	No	No	25
Nursing care	Gerontologic research priorities	46	4	No	No	26
Nursing	Administrative research priorities	88	3	No	No	27
Nursing care	Research priorities	367	3	No	No	28
Nursing care	Research priorities	715	2	No	No	29
Nursing care	Mental health research priorities	84	3	No	No	30
Nursing care	Health and safety research priorities	1130	2	Yes	No	31
Hospital management	Problem solving	25	3	No	No	32
Allied health education	Forecast future developments	10	3	No	No	33
Nursing education	Future practice	40	3	No	Yes	34
Hospital education	Needs and future practice	26	3	No	No	35
Education	Priorities for school health	200	3	No	No	36
Nursing	Research priorities	2623	3	No	No	37
Medical education	Promotion for family practice residents	21	3	No	No	38
Physician assistant education	Future roles	50	4	No	No	39
Education	Future gerontology curriculum	97	3	No	No	40
Nursing education	Maternal child curriculum	20	4	No	No	41
Medical education	Blood bank curriculum	75	2	No	Yes	42
Medical education	Blood bank competencies	171	2	No	Yes	43

cast of the group improves because of this interaction.[14] Scheibe et al[45] tested the feedback mechanism and noted that false feedback influenced the group. It is important to the execution of a Delphi study that appropriate representation of comments and statistical group response be controlled.

Lastly, participants receive the statistical group response of the entire group for a single question or item.[13,14] For feedback purposes, a Likert-type scale may be utilized from which a mean or median is obtained. Each member may compare his response to that of the group. This feedback is important in fostering convergence of opinion and eventual consensus determination. Other characteristics related to validity and reliability of method include questionnaire design, number of participants, consideration of the questionnaire by the experts, and attrition.[14,15]

Dalkey reported a reliability coefficient as high as 0.76 in a systematic study that correlated the responses of pairs of panels of varying size.[46] He noted an increase in reliability as group size increased from 3 to 11. Dagenais studied the reliability of the technique and confirmed the theory and previous research about how the Delphi technique functions and its reliability.[47]

Many studies have used panels of hundreds and even thousands of participants (Table 1). Barnette

et al concluded that large-scale Delphi surveys have many disadvantages and should be reconsidered.[48] Other investigators consider the size of the expert panel to be appropriate with 20-30 individuals.[15,49]

Methodology

Selection of Experts

In the Delphi method, the selection of experts is an important step and a difficult task because the method uses experts and not random sampling. In order to represent all major components of the respiratory care community, we identified respiratory care clinical practitioners, educators, managers, and medical directors as the four primary groups of experts necessary to participate. Because the investigators considered the judgments of each group equally important and valid, and in order to minimize domination by any single constituency, we stipulated that these four primary groups would participate, in similar proportions. The numbers of experts requested and invited, and the numbers of experts who accepted the invitation and who participated are detailed in Table 2.

Nominations of the clinical practice, education, and management experts were solicited from the specialty sections of the AARC. Nominations for physician experts were requested from the National Association of Medical Directors of Respiratory Care and from the Board of Medical Advisors of the AARC. Both organizations were requested to nominate up to 16 medical experts. Members of the 1988 and 1989 Education Committee of the AARC were specifically excluded from participating as experts in the study.

Based on the peer nominations and considering the possibility of duplication of some nominations, the committee initially invited a total of 114 experts to participate; these 114 experts were the population of nominated experts. Eighty experts initially accepted our invitation. These 80 experts included 26 clinicians, 24 managers, 22 educators, and 8 physicians. After completion of the first round it was noted that only 6 physicians had participated. The committee invited 11 additional physicians associated with the NBRC and the Joint Review Committee for Respiratory Therapy Edu-

Table 2. The Distribution of Experts in the Panel of the AARC Delphi Study

Expert Groups	Number Requested	Number Invited	Number Accepted	Number Participated
Clinical Practitioners	32 (24%)	32 (26%)	26 (29%)	24 (28%)
Cardiopulmonary	8	8	5	5
Continuing care	8	8	7	7
Perinatal/pediatrics	8	8	7	7
Adult cute care	8	8	7	5
Educators	32 (24%)	32 (26%)	22 (24%)	21 (24%)
Proprietary	8	8	3	2
Vocational-technical	8	8	4	4
Community college	8	8	9	9
4-year college/university	8	8	6	6
Managers	38 (28%)	32 (26%)	24 (26%)	23 (26%)
Small hospital (1-199)	8	7	4	4
Medium hospital (200-399)	8	7	6	6
Large hospital (400+)	8	8	6	6
Non-acute care	8	4	4	3
Specialty facilities	6	6	4	4
Medical Directors	32 (24%)	29 (23%)	19 (21%)	19 (22%)
Total	134	125	91	87

cation (JRCRTE) to participate in the study. The number of physician participants increased to 19, and the total number of participants increased to 91 for Rounds 2 and 3. Between the completion of Round 3 and the mailing of Round 4, 1 participant had left the professional practice of respiratory care, and the panel of experts was reduced to 90 for the fourth round.

Instrumentation

This study involved four sequential surveys of the panel of experts. Committee members, consultants, and selected expert participants field-tested the final draft of each questionnaire for completeness of instructions and clarity of the instruments. The first survey was mailed to 80 participants in January 1989. The primary sections of this questionnaire were an introductory letter explaining the Delphi process, background information explaining the working assumptions of the study, and the primary open-ended question requesting a list of abilities, traits, and characteristics necessary for the respiratory care practitioner of the future.

Design of the Round 2 questionnaire was based on the responses received from participants in Round 1. All of the 427 responses from Round 1 were discussed by a 5-member subcommittee and placed into 1 of 5 categories: cognitive, technical, attitudinal and social, psychosocial, and learning skills. The subcommittee generated a comprehensive and mutually exclusive listing for each category. The resultant questionnaire for Round 2 delineated 100 items that were to be rated by the experts in terms of importance (priority or relevance) using a 4-point Likert-type scale with 4 indicating "very important," 3 indicating "important," 2 indicating "unimportant," and 1 indicating "very unimportant." Participants were encouraged to comment on any item to clarify its meaning or to express agreement or disagreement. Nominations for additional items were permitted in this round, which afforded the opportunity for the 11 additional physician-experts to introduce items. This second questionnaire was mailed to the initial 80 participants and the additional 11 physicians at the end of March 1989.

The design of the third questionnaire was developed from the responses of the participants in Round 2. In the third round, experts were requested to justify excluding items previously determined "important" or justify retaining items previously determined "unimportant." In the third round, participants were also provided and asked to consider all of the comments, the importance ratings, and the overall rankings of a third group of items about which a consensus was not yet clear. To come to a consensus on these items, the Likert-type scale for Round 3 specified 4 as "very important," 3 as "important," 2 as "not very important," and 1 as "unimportant." Ninety-one questionnaires were mailed for Round 3 in May 1989.

The subcommittee determined from Round 3 responses that a fourth questionnaire should allow the experts to predict what items would be necessary for entry into practice, necessary for advanced practice, or neither. Participants were asked to review all items previously determined "important" for all practitioners in the future on the Round 4 questionnaire. After reviewing the mean and percent rating "very important" and comments for those items about which consensus was not yet clear, experts were requested to consider and rate a second listing of items close to consensus in terms of whether each item was necessary for basic or advanced practice or neither. The questionnaire was mailed to 90 participants in June 1989.

Data Collection and Analysis

The committee conducted this study between January and July 1989. Questionnaires were mailed with cover letters, and participants who were late with return of their questionnaire were contacted by telephone to ensure their continuing participation in each round. A χ^2 test for goodness of fit was performed on the distribution of respondents for each round. The number of respondents was compared with an expected equally proportionate distribution for all four categories of experts. Statistical significance was defined by the committee as $p < 0.05$.

Data analysis for Round 1 consisted of catgorizing all 427 responses received from the participants. As previously noted, these written responses were compiled and reflected in the 100 items included in the Round 2 questionnaire.

Analysis of Rounds 2 and 3 utilized descriptive statistics (frequency distributions, means, modes,

and standard deviations). Statistics were computed for each of the 100 statements of characteristics, traits, and attributes. Prior to analysis of results, a subcommittee working with consultants determined the appropriate level of consensus for each questionnaire. For an item to be considered "important," we defined consensus as greater than 50% of the experts rating an item as "very important" or when the sum of "very important" and "important" ratings was 75% or greater. For an item to be considered "unimportant," we defined consensus as greater than 50% of the experts rating an item as "not very important" or as "unimportant."

Analysis of the responses of the Round 4 questionnaire determined the categories for the items "as necessary for entry-level," "necessary for advanced-level," or "not necessary for either level." For an item to be retained as "important," more than 75% of the respondents indicated that the item was necessary for either entry-level or advanced-level. For an item to be appropriate for entry-level more than 50% of the respondents indicated that the item was necessary for entry-level. For an item to be appropriate for advanced-level, more than 50% of the respondents indicated that the item was necessary for advanced-level.

Results

In Round 1, 68 (85%) of the 80 experts participated, and 80 (88%) of the 91 experts returned the Round 2 questionnaire. Eighty-four (92%) of the 91 participants returned the Round 3 questionnaire, and 75 (83%) of 90 participants returned the Round 4 questionnaire. The overall participant response rate for the entire project was 87%.

Table 3 details the distribution of respondents by major panelist category for all 4 rounds. The χ^2 analysis of the distribution of respondents, compared to an expected equally proportionate distribution for all four categories for Round 1, indicated that there was a disproportionate distribution; medical experts were not fully represented. With the addition of the physicians associated with the NBRC and JRCRTE, the χ^2 results for Rounds 2, 3, and 4 indicated a proportionate distribution by major group category.

Round 1 generated 427 items thought to be relevant to the abilities, traits, and characteristics of future respiratory care practitioners. In Round 2, participants reached consensus on 33 of the 100 composite items. Twenty-five items were determined "important," and 8 items were determined "unimportant." In Rounds 3 and 4 the ratings of these items did not change. Tables 4-6 list important knowledge and cognitive skills, psychomotor and clinical skills, and attributes needed by all future respiratory care practitioners according to the experts. The experts did not reach a consensus on 67 additional items in Round 2. During Round 3, when these 67 items were reconsidered by the

Table 3. The Distribution of Experts by Major Group Category for Each Round of the AARC Delphi Study

	Expert Group Categories					
	Clinicians	Educators	Managers	Physicians	Totals	χ^2
Round 1						
Mailed	26	22	24	8	80	10.25
Returned	23	19	20	6	68 (85%)	($p < 0.05$)
Round 2						
Mailed	26	22	24	19	91	3.70
Returned	24	16	23	17	80 (88%)	($p > 0.05$)
Round 3						
Mailed	26	22	24	19	91	1.26
Returned	24	21	20	19	84 (92%)	($p > 0.05$)
Round 4						
Mailed	26	21	24	19	90	1.50
Returned	20	18	20	17	75 (83%)	($p > 0.05$)

Table 4. Important Knowledge and Cognitive Skills Needed by Future Respiratory Care Practitioners as Determined by the AARC Delphi Study

Knowledge	Cognitive Skills
Biology (80)*	Reading skills (100)
Chemistry (83)	Adequate math skills (98)
Physics (85)	Organizational and time management skills (94)
Microbiology (89)	Communication skills (oral, written, and listening) (99)
Human anatomy and physiology (100)	Critical thinking abilities (analytical skills, problem solving, judgment, decision making) (100)
Medical terminology (100)	
Pathophysiology (93)	
Pharmacology (95)	
Hemodynamics (97)	
Professional roles and functions (91)	
Respiratory care theories and procedures (100)	
Basic pulmonary function testing (100)	
Neonatal and pediatric care (99)	
Home care equipment and procedures (96)	
Health promotion/disease prevention (89)	
Understanding of cost containment (89)	
Medical-legal aspects of practice (89)	
Ethics (89)	

* Numbers in parentheses are percent of panelists who believed the topic to be important.

panel of experts, 28 items were rated as "important" or "very important"; these additional 28 items are included in Tables 4-6. The experts did not reach a consensus for the remaining 39 items at the end of Round 3. Because of the comments received, 3 items were added by the committee in order to differentiate between "knowledge of" and "proficiency in" basic pulmonary function testing, between "knowledge of" and "proficiency in" neonatal and pediatric care, and between "management-oriented" and "patient-oriented" interviewing skills. This adjustment resulted in 42 items for which there was not yet clear consensus to be reconsidered in Round 4.

Table 5. Important Psychomotor and Clinical Skills Needed by Future Respiratory Care Practitioners as Determined by the AARC Delphi Study

Respiratory care implementation, planning, and evaluation (99)*
Proficiency in basic therapeutics (eg, gases, IPPB, aerosols) (94)
Proficiency in ventilator management (99)
Proficiency in respiratory mechanics (93)
Proficiency in basic pulmonary function testing (95)
Patient assessment skills (eg, vital signs, breath sounds) (99)
Blood gas sampling, analysis, and quality control skills (93)
Airway management skills (99)
Patient education skills (95)
Proficiency in infection control (90)
Interview skills, patient oriented (93)
Physical ability to do work (89)

* Numbers in parentheses are percent of panelists who believed the topic to be important.

In Round 4, the experts rated 16 of the 42 items as necessary for entry-level and 11 items as appropriate for the advanced level. The additional entry-level items are included in Tables 4-6; the additional items necessary for the advanced level are listed in Table 7. Six items were determined as necessary for the respiratory care practitioner in the future, although there was no consensus on the level at which they should be introduced (Table 8). The experts rated 10 of the 42 items as "unimportant." The level of consensus for each item is listed in Table 4-8 in terms of the percentage of experts who projected the importance of item necessary for the future.

Discussion

Limitations and Assumptions of the Study

Readers should carefully consider the limitations and assumptions when evaluating the results of any Delphi study. In terms of the number of respondents for the panel of experts, two considerations must be noted. First, Delbecq has documented that few new ideas are generated within a homogeneous group when the number of the group exceeds 30 expert participants.[49] Delphi studies have included as few as 10 and as many as 2,623 participants. For

Table 6. Important Attributes and Characteristics Needed by Future Respiratory Care Practitioners as Determined by the AARC Delphi Study

Sensitivity to and respect for the needs of others (100)*	Health-oriented behaviors (81)
Dependability/reliability/ responsibility (maturity) (99)	Assertiveness (81)
Flexibility (ability to adapt to change) (99)	Interpersonal skills (team work, conflict resolution) (98)
Ability to handle stress (98)	Willingness to learn (99)
Conscientiousness (hard-working, high standards) (97)	Professionalism (image, pride, career-versus-job attitude) (98)
Integrity (honesty, sincerity, ethical behavior) (99)	Commitment/dedication to profession (98)
Compassionate, caring, empathetic (95)	Motivation for continuing learning (96)
Courtesy, tactfulness (96)	Growth though educational activity (94)
Self-motivation (initiative) (98)	Ability to give and receive criticism (96)
Patience and understanding (95)	Ability to effect and manage change (90)
Desire to help others (98)	Self-directed learning skills (96)
Self-direction (95)	Enjoyment of learning (91)
People-orientation (humanism) (95)	Credentials (95)
Self-esteem/confidence (94)	Determination/ perseverance (98)
Friendliness and being personable (91)	Goal orientation (95)
Tolerance (87)	Loyalty to colleagues and institution (84)
Respect for authority (90)	Positive outlook/sense of humor (88)

*Numbers in parentheses are percent of panelists who believed the topic to be important.

this study, a slightly greater number of nominations than considered necessary were requested due to the possibility of duplication of nominations. In this manner, we were able to avoid panelists from the same institution and minimize geographic imbalance (36 states were represented). Moreover, a slightly larger number of experts than recommended by Delbecq was preferred in consideration of the diversity and geographic distribution of the population. Second, a somewhat similar methodologic assumption is that the selected experts of this study are representative of experts in various areas involved with the education and practice of respiratory care practitioners. In order to facilitate selection of an effective panel of experts and to generate a broad base of support for the study, participants were requested for nomination

Table 7. Additional Knowledge, Skills, and Attributes Important for Advanced Level Respiratory Care Practitioners, as Determined by AARC Dephi Study

Proficiency in neonatal and pediatric care (93)*
Proficiency in pulmonary rehabilitation (89)
Proficiency in respiratory care home care techniques (83)
Proficiency in Advanced Cardiac Life Support (ACLS) (87)
Proficiency in quality assurance methods (84)
Proficiency in respiratory care computer applications (79)
Exercise and stress testing (83)
Bedside hemodynamic monitoring skills (91)
Leadership skills (77)
Specialization (88)
Ability to interpret research (75)

*Numbers in parentheses are percent of panelists who believed the topic to be important.

based on criteria developed by Delphi experts.[11,16,45,49] Involving the AARC specialty sections in the nomination process served several purposes. Section members could identify individuals who were "well known and respected" in their particular areas, thus supporting criterion for selection of panelists who would have expert knowledge to share with other panelists. Being nominated by their peers should also contribute to the panelists' feelings of personal involvement and enhanced motivation. Subsequently, the specialty sections, primarily clinicians, would have the assurance that selected participants were familiar with the special needs and concerns considered unique to their specialty. Nominations of experts from the areas of medical direction, education, and management was

Table 8. Additional Knowledge, Skills and Attributes Important for Respiratory Care Practitioners as Determined by AARC Delphi Study, with No Consensus Reached on Level

Willingness to get involved and be proactive (88)*
Creative and innovative skills (80)
Ability to function in alternate sites (86)
Knowledge of health care regulations (81)
Knowledge of computer science (79)
Knowledge of gerontology (76)

*Numbers in parentheses are percent of panelists who believed the topic to be important.

considered important for the same reasons. Experts from related organizations could be expected to broaden the panel's perspective, share relevant information, and build support for the conclusions. There is no perfect formula to the size or panel makeup, only guidelines. Kurtzman has noted "There are no right answers when it comes to how large they should be or how varied. It is better to think in terms of structuring a panel so that information can flow between the experts to spark their creativity and critical powers of analysis."[50]

Another limitation of the Delphi technique is that the validity of the predictive power for forecasting may be questionable because proof can only be established with the passage of time. Proponents of the method assert that the attributes that contribute to authentic consensus and valid results are derived from anonymity of panelists, statistical response, and iterative questionnaires with feedback.[51]

Helmer has pointed out that relatively few experiments have been done to validate the predictive power of the Delphi for two major reasons. One reason is clarified by the realization that long-term forecasts "cannot be verified until a sufficiently long time has elapsed" and equally important, "to validate the method properly, experts would have to be used as laboratory subjects."[11]

Strengths of the Study

Although, this study is limited by the methodology in the sense that projections are largely based on the personal expectations of individuals rather than on predictions from theory.[11,12,16,45,46,49] Critics tend to rationalize the results of the consensus as being one-dimensional rather than examining the usefulness of the forecast for planning and policy formation. However, consider that expert panelists delineated educational preparation for entry into practice without quantification of the actual content for each item determined for entry level. Consequently, panelists were able to project future needs from their personal expectations rather than through quantification of delineated curriculum, depth, or defined time necessary for each potential curriculum item.

The Delphi methodology was selected because of its ability to minimize the influence of dominant personalities, remove geographic limitations, and solicit input from experts who otherwise might not participate. To assure validity and reliability, we utilized all of the characteristics of the Delphi technique. We utilized all of the experts from the 4 major constituencies who were willing to participate, and the experts remained anonymous throughout the inquiry. Repeated questioning of each participant with a series of 4 questionnaires and feedback permitted consideration of all responses and comments without allowing the experts to interact directly with one another.[11,49]

Study Findings: Possible Implications for Curricula

According to the panel of experts, all respiratory care practitioners of the future will continue to need a broad base of knowledge in the sciences. This scientific basis for practice will to include knowledge of human anatomy and physiology, biology, chemistry, physics, microbiology, pathophysiology, and pharmacology. The guidelines for the 1986 Essentials suggest these basic sciences.[2] Previous Essentials required these sciences. Our study supports the inclusion of these sciences in the curricula of all respiratory care educational programs.

Some items considered important by the experts are not specifically suggested in the 1986 Essentials and Guidelines;[2] these include knowledge of health promotion and disease prevention, cost containment, medical-legal aspects of respiratory care, and professional roles and functions. Knowledge of hemodynamics was identified as important for all future practitioners; the 1986 Essentials and Guidelines suggest a broader knowledge of "cardiopulmonary monitoring and interpretation."[2] A course, module or unit on communication skills was required by the 1977 Essentials and Guidelines;[52,53] communication skills were identified as important by our experts, even though communication skills were deleted from the curricular suggestions in the 1986 Essentials and Guidelines.[2]

According to the panelists, the future practitioner will need to be proficient in the application of adequate mathematics and reading skills. Although the mathematics and reading levels were not specifically determined in this study, some pre-

vious studies may be relevant. Watson and Scully assessed the average reading level of 11 commonly used respiratory care textbooks and found reading levels to be Grades 14 through 17.[54] Watson also analyzed the reading levels of 9 respiratory physiology textbooks and found reading levels from Grades 14 through17.[55] Chang, in an analysis of of 6 commonly used respiratory care textbooks and a NBRC RRT Written Self-Assessment Examination; found reading levels of the textbooks from Grades 13 through 17 and of the examination from Grades 8 through 12.[56] The reading levels of the analyzed textbooks reflect 1 to 6 years of postsecondary education, and of all the textbooks analyzed, only one had a reading level that coincided with less than 2 years of postsecondary education. The reading skills requirement may have implications for appropriate admissions and curricular requirements as well as for the duration of postsecondary education.

The panel's perceptions of the educational needs of future practitioners related to clinical skills provided few new insights, but rather served to confirm much of what is already known. The experts did identify blood gas quality control skills as needed for entry level; whereas in the 1986 NBRC job analysis these skills were identified for the advanced-level.[57] Consistent with the 1986 Essentials and Guidelines, the panel of experts identified airway management skills as needed for all future respiratory care practitioners; whether these skills include intubation, tracheostomy care and tube changes, as identified by the NBRC for advanced-level practice, remains unclear.[57]

One of the most important findings of this study is that almost half of the characteristics, traits, and attributes considered important by the experts are related to the affective domain. Some of the attributes considered important are primarily personal; these may have implications for admission criteria and decisions for educational programs. Some important attributes are professionally related; these may have curricular implications. Although the 1986 Essentials and Guidelines encourage programs to incorporate general education, liberal arts, and humanities in curricula, only psychology is specifically suggested.[2] The results of this study suggest a greater importance for the affective domain for respiratory care practitioners in the future. The number of attributes identified as important by the panel of experts appears to lend support for affective evaluation of students and inclusion of affective objectives in the standards of accredited programs.

In 1985 and 1987 important changes in the scope of practice of respiratory care practitioners were described by the Task Force on Professional Direction of the AARC.[9] Walton and Sullivan reported that 657 (51%) directors of respiratory care services from hospitals of various sizes and regions of the country responded and that almost 54% of the responding directors reported that their departments offered health promotion services; 47% reported that their departments offered noninvasive cardiac diagnostic services, and 21% offered "other nonrespiratory services." Improving efficiency was identified as the most common reason for adding services, and 73% felt that the need for cross-utilization of respiratory care professional will increase.[9] Our study confirms the importance of knowledge of health promotion and disease prevention and patient education skills consistent with the results of the AARC Task Force.

Study Findings: Possible Implications for Credentialing

The NBRC performed job analyses for entry-level and advanced-level practitioners in 1986 and made some modifications in the examination matrices for the July 1988 and 1989 entry-level and the December 1988 and 1989 advanced-level multiple choice examinations.[57] The NBRC reduced the number of tasks that can be tested on the entry-level examination from 317 to 278, reduced the complexity of the examination by asking 3% more recall questions, 2% fewer application questions, and 1% fewer analysis questions, and reduced the number of items on the examination from 200 to 140.[57] The NBRC increased the number of tasks that can be tested on the advanced-level exam from 137 to 305.[57] According to the number of tasks associated with each level, from 1981 to 1986 the NBRC-defined entry-level scope of practice decreased by 12% while the advanced practitioner's scope of practice more than doubled. Our experts identified 69 items important for entry-level and only 10 items were considered important

for the advanced-level. According to the panelists, these 10 items will comprise the collective distinction between entry-level and advanced-level practitioners in the future. For several of these items, the experts considered knowledge important for all practitioners, but proficiency important for advanced practice. Development of proficiency in these areas may have implications for necessary clinical resources, curriculum, clinical objectives, and student evaluation in programs accredited at the advanced-level in the future. The difference in the proportions of entry-level and advanced-level tasks as described by the NBRC and by our items may be related to future developments in the profession as predicted by our experts.

Other studies and surveys have reviewed changes in the duration of education and clinical experience required for NBRC credentialing.[58-61] The NBRC initiated the current entry-level and advanced-level examination system in 1983. NBRC credentialing examinations have been based upon national job analyses conducted in 1981 for entry-level, in 1982 for advanced-level, and in 1986 for both levels simultaneously.[57,62,63] Consistent with examining for entry-level, the NBRC eliminated the requirement of the additional year of clinical experience for graduate technicians in 1983, and beginning with the December 1988 examination the NBRC eliminated the required additional year of clinical experience for graduate therapists to qualify for the advanced-level examination (registry). Considering the minimum required sum of training and experience for credentialing, the NBRC now requires less time to obtain credentialing as a respiratory therapist than was required in 1970, and less time for credentialing as a respiratory therapy technician than in 1974.

Study Findings: Possible Implications for Program Length

Consistent with the "product-oriented" philosophy of accreditation, the 1986 Essentials and Guidelines do not specify nor suggest a minimum duration of curriculum for respiratory therapy technicians or respiratory therapists. According to the 1986 Essentials, "the length of the curriculum ... shall be consistent with the identified goals and standards of the program and its sponsoring institution(s)."[2] Programs accredited through the JRCRTE must assure "that graduates demonstrate at least entry-level competencies, as periodically defined by nationally accepted standards of practitioner roles and functions ... as periodically developed by the appropriate professional organizations."[2] This study has predicted the future educational needs of respiratory care practitioners and may be helpful to educators to guide curriculum development in the future.

Several independent investigators have studied questions concerning the educational preparation and credentialing of respiratory care practitioners. In 1984 Flanigan and Harris demonstrated a statistically significant difference ($p < 0.01$) in entry-level examination pass rates between accredited therapist and technician educational programs.[58] Flanigan and Harris compared the reported technical curricular content areas in technician and therapist programs of eight therapist and eight technician programs. They concluded that the 2.5% reported difference in technical curricular content areas could not explain the significant differences in pass rates, and (although they may not have considered any differences in admission requirements or academic standards of the programs they studied) concluded that students may need the additional year of patient contact and didactic time available in therapist programs to fully grasp the entry-level skills as measured by the examination.

Scanlon studied 179 educational programs that had undergone recent accreditation site visits and reaccreditation reviews.[59] Using mean scores on the March and July 1983 entry-level examinations as the dependent variable, he compared examination performance with compliance with the 1977 Essentials. In regard to curriculum, Scanlon's regression analysis indicated that above average performance on the examinations was associated with curricular durations in excess of 18 months. Scanlon also documented a statistically significant difference ($p < 0.001$) between mean scores of graduates from technician and therapist educational programs. It should be noted that the average performances for graduate technicians were mean scores of 74 and 72, which were less than the minimum passing score of 75, whereas, 79 and 78.5 were the means for new therapist graduates in 1983.

Using a nationwide random sample of 25 technician programs, 25 therapist programs, all 25 baccalaureate programs, and 2 additional volunteer programs listed in the roster of accredited education programs of the JRCRTE, O'Daniel described program characteristics and curricular components and their relationships to new graduate performance on the 1984 entry-level examinations.[60] For selected program characteristics, O'Daniel found significant variability among programs types as well as among programs of a single type. O'Daniel identified strong correlations between entry-level examination performance and the total number of instructional hours and the number of hours in each phase of instruction (classroom, laboratory, and clinical) for graduate therapists and between total general-science instructional hours and technician-graduate examination performance. O'Daniel concluded that the graduates of 2-year associate degree therapist programs appeared to be the most appropriately prepared for entry into respiratory care practice.

The lack of specificity in the 1986 Essentials and Guidelines did cause some concern in the educational community prior to implementation. In 1984, Douce and Wiezalis surveyed 351 program directors of all accredited programs on their opinions and attitudes toward the proposed 1986 Essentials; 218 (62%) program directors responded.[61] At that time 55% of the respondents agreed or strongly agreed that the Essentials should require a 2-year or an associate degree entry-level, and 55% of the respondents agreed or strongly agreed that the Essentials should require a minimum of 62 semester hours of college credit for entry-level.[61]

In an effort to draw a profile of successful respiratory care students, von der Heydt surveyed all 455 accredited educational programs in 1988.[64] Program directors were asked to identify their top 10 most successful male and female graduates and to describe them using a questionnaire. Although only 98 (22%) program directors responded, this survey found that 69 of the successful graduates had been enrolled in postsecondary education before enrolling in a respiratory care program.

In Conclusion

In conclusion, the 1989 AARC Education Committee used the Delphi process to determine the future educational needs of respiratory care practitioners. We believe that our selected panel of experts was representative of experts in all major areas involved with the education and clinical practice of respiratory care and that group responses utilizing experts are more reliable than individual expert opinions.

The results of this study provide the basis for further research in education for respiratory care practitioners including the specific content for each item and development of curricular options for integrating these findings into the respiratory care educational system and for the minimum duration of educational preparation for entry-level and advanced practitioners.

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Bilateral Hilar Masses in a 32-Year-Old Man?

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A 32-year-old man presented with an intermittent cough of 2-week duration that produced yellow sputum and specks of blood. At age 12, he had undergone repair of atrial and ventricular septal defects but was left with persistent pulmonary hypertension. At age 21, he had experienced an episode of subacute bacterial endocarditis and over the 10 years prior to this admission had had recurrent episodes of bronchitis, pneumonia, and sinusitis, with progressive dyspnea. He had recently been started on home oxygen. The patient had never smoked, and there was no other family history of congenital heart disease.

Examination revealed temperature 97.2°F, heart rate 105 beats/min, respiratory rate 22 breaths/min, and blood pressure 108/78 mm Hg. Jugular vein distention, enlarged liver, and pedal edema were present. Auscultation of the heart revealed a laterally displaced precordial heave, a Grade II/VI subxiphoid systolic murmur, and a Grade I/VI diastolic murmur at the left sternal border. Basilar rales with egophony over the right midthorax were evident. Pulses were full bilaterally. No clubbing was observed.

Sputum examination revealed a mixed flora. Blood tests revealed white blood count 8.3×10^3/mm^3, hemoglobin 16.4 g/dL, hematocrit 49.3, and normal platelet and clotting results. The test for tuberculosis (PPD) was negative. Analysis of blood drawn while the patient breathed room revealed P_{aO_2} 46 torr, P_{aCO_2} 31 torr, and pH 7.56. With oxygen at 2 L/min by nasal prongs, P_{aO_2} rose to 65 torr. Electrocardiogram showed sinus rhythm with right-axis deviation and right-atrial and ventricular enlargement. Pulmonary function tests showed FEV_1 1 L and FVC 2.79 L. Bronchoscopy showed only mucosal edema and erythema, without lesion or deformity. The chest radiograph is shown in Figure 1.

Fig. 1. Posteroanterior chest radiograph of 32-year-old man with cough and sputum production for 2 weeks.

Questions

Chest Radiograph Findings: What does Figure 1 suggest?
Differential Diagnosis: What possibilities should be considered in the differential diagnosis?
More Likely Diagnosis: Given the patient's history and presentation, what is the more likely diagnosis?
Further Tests: What additional diagnostic procedure is indicated?

Answers and Discussion on Next Page

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Answers

Chest Radiograph Findings: Figure 1 suggests (1) bilateral hilar masses or (2) vascular dilatation.

Differential Diagnosis: (1) Bilateral hilar masses could represent enlarged lymphatic nodes of sarcoidosis, berylliosis, or lymphoma. Bronchogenic carcinoma is unlikely with bilateral hilar involvement. Cystic fibrosis and silicosis may cause bilateral reactive hyperplasia of hilar nodes usually associated with parenchymal infiltrates. Rare causes of bilateral hilar enlargement include histiocytosis X, idiopathic pulmonary hemorrhage, angioimmunoblastic lymphadenopathy, and bronchopulmonary amyloidosis. (2) Vascular dilatation could be a consequence of the patient's congenital heart defects and persistent pulmonary hypertension.

More Likely Diagnosis: Vascular dilatation is the more likely diagnosis given this patient's history and presentation.

Further Tests: Computed tomography (CT) of the thorax is indicated to further delineate the chest radiographic findings (Fig. 2).

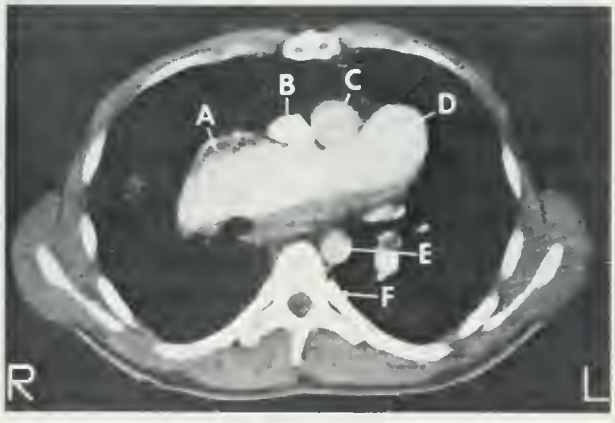

Fig. 2. Computerized tomography section of the thorax of the man whose chest radiograph is seen in Figure 1. The section is taken from just below the bifurcation of the trachea at the origin of the pulmonary arteries. A = clot in pulmonary artery aneurysm (PAA); B = superior vena cava; C = ascending aorta; D = PAA; E = descending aorta; F = spine.

Computed Tomography Findings: Figure 2 shows a section of the CT scan taken below the bifurcation of the trachea at the origin of the pulmonary arteries. Contrast clearly fills massively dilated pulmonary artery aneurysms.

Discussion

Pulmonary artery aneurysms (PAAs) are rare and are frequently associated with other factors. One half of PAAs are associated with congenital defects of the heart, with patent ductus the most common, followed by defects of the atria and ventricles.[1,2] Infections involving the vessel walls commonly complicate PAAs. Before effective antibiotics were available, tuberculosis and syphilis were frequently implicated.[2] Persistent pulmonary hypertension (as in our patient) contributes to progressive dilatation because of the Law of LaPlace (T = PR/2). Structural defects of the pulmonary arteries have been implicated in the pathogenesis of PAAs whether congenital (eg, cystic medionecrosis of Marfan's syndrome[1,3] and hereditary hemorrhagic telangiectasia) or acquired (eg, vasculitis of Behcet's disease[4] or trauma from presence of a pulmonary artery catheter).[1,5]

Patients with PAA can present with hemoptysis, chest pain, cough, and symptoms of right heart failure. If the aneurysm provides an arteriovenous communication, cyanosis and clubbing as a consequence of the right-to-left shunt or central nervous system signs secondary to paradoxic emboli can be present. The electrocardiogram may show signs of right ventricular enlargement and right axis deviation. A chest radiograph may show obvious enlargement of the vasculature; however, PAAs have been mistaken for solitary nodules and have even been biopsied.[6] Definitive diagnosis commonly requires angiography or CT. Magnetic resonance imaging and echocardiography may be helpful when contrast is contraindicated.[7]

Attempts should be made to treat infections or surgically correct cardiac defects associated with PAAs. Aneurysms affecting the main pulmonary trunk or arteries require surgical correction by aneurysmectomy, aneurysmorrhaphy, repair with suitable graft material, or repair with a patch of pericardial tissue. Smaller distal aneurysms, particularly those with right-to-left shunts can be embolized with wire coils, detachable balloons, or gel foam.[8] The location and extent of some aneurysms may dictate resection of part or all of an entire lung if pulmonary reserve permits.

Our patient was treated for acute bronchitis with oral cefaclor. Over the course of the following year,

he developed progressive right heart failure. He subsequently developed pneumonia and died.

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INSTRUCTIONS FOR AUTHORS

In addition to case reports strictly involving pulmonary-medicine radiography, case reports involving adult, pediatric, and neonatal critical-care radiography can also be submitted to the 'Test Your Radiologic Skill' corner. However, all case reports should relate somehow to respiratory care. Illustrative radiographs may be of routine chest exams or of other less-common exams such as digital subtraction or computerized axial tomography.

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Cardiopulmonary Pharmacology: A Handbook for Respiratory Practitioners and Other Allied Health Personnel, by Cynthia L Howder. Soft-cover, 315 pages, illustrated. Baltimore: Williams & Wilkins, 1991. $33.00.

The subject of respiratory pharmacology has been well covered in the past decade, although there are no treatises that approach the encyclopedic work of Ziment, published in 1978. This handbook encompasses not only the drugs used by the respiratory practitioner but also those employed in critical care. It is aptly called a handbook, summarizing the information most needed by the clinician when facing a life-threatening crisis.

This book is divided into two sections, the first on general pharmacology, the second on the several classes of drugs utilized in respiratory and critical care. Section I is primarily directed to the respiratory care student; general principles and mechanisms are described. Each of the chapters (6 in number) begins with a set of objectives, providing a quick overview of what the chapter is about. The format is conservative, following the sequence of topics usually found in pharmacology texts. A useful glossary and table of abbreviations is included in Chapter 1. Chapter 3 is mainly concerned with bronchopulmonary physiology and the administration of aerosols. No summaries of pharmacokinetic and pharmacodynamic formulas are included; the treatment of these subjects is nonquantitative. Chapter 6 is devoted to the mathematics of dosage calculation, with a group of illustrative problems added.

Section II comprises the major portion of the book and is divided into 14 chapters. Objectives are listed in the introduction to the section and are intended to apply to each of the chapters. The drugs encountered in respiratory care are well covered in Chapters 7-18. Chapter 19 is a review of resuscitation drugs, as presented in the Advanced Cardiac Life Support (ACLS) Guidelines, a worthwhile addition. Chapter 20 deals with critical care drugs and includes diuretics and anticonvulsants as well as cardiovascular agents.

There are four appendices. The first is an assessment test, which I found disappointing. Generic and trade names were intermixed, and a few of the questions could have been rewritten for greater clarity. Construction of good test items is a difficult, almost specialized pursuit. The book would not be harmed if this part were omitted. The other three appendices provide the reader with approximate dose equivalents, a list of orphan drugs and their proposed uses, and a bibliography. The index is definitely superior, running to 32 pages.

This handbook would be an admirable textbook for a pharmacology course of 2 or 3 credit hours in the respiratory care curriculum. Students would profit from the clear organization of the work, and the emphasis on practical facts and figures. Illustrations, tables, and charts are provided in abundance, lessening the tasks of rote memory for the novice. Having profited from this introduction, the student could continue to use the handbook as a reference source in the clinic. The author ably bridges the gap between basic science and clinical application. Allied health teachers will find this pharmacology book a welcome addition to their libraries.

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Letters

Pressure Control Ventilation—Another View

I read with interest the letter by Mr Chatburn in the August issue of RESPIRATORY CARE.[1] I believe that Mr Chatburn was fundamentally correct in his statements that volume can rupture alveolar units; however, pressure does play an extremely important role in barotrauma and cardiac function.[2-7]

Mr Chatburn's statement about the balloon encased in a metal cylinder and withstanding thousands of centimeters of water pressure is 'nice', but I know of no living person whose lungs are encased in steel. The point is that during a disease process such as ARDS the lungs become very stiff and noncompliant, leading to lung units with major differences in compliance and resistance. Frequently, the clinician must use higher PEEP and higher peak pressures to provide the same tidal volume. At this point it is not the 'normal tidal volume' that plays the major role in barotrauma but the higher peak and PEEP pressures that cause further lung damage.[8] High pressures associated with uneven expansion can cause pneumothoraces and pneumomediastinum. Also the shear forces accompanying nonhomogenous expansion of lungs can be considerable.[9-13] Such forces may well be a major reason for structural damage, especially to the bronchiolar epithelium.[14-18] Potentially damaging shear forces appear in the zone between opened and closed compartments within the lungs and may be particularly important when closure and opening of lung units occur during each breathing cycle. The ventilatory support of ARDS should thus open up closed units and keep them stable and should avoid local or generalized hyperinflation. In ventilator management of the patient with ARDS the following should be considered:

- One must overcome a critical opening pressure during inspiration
- This opening pressure must be maintained for a sufficiently long period of time.
- During expiration no critical time that would allow closure of lung units should pass.[19]

The critical opening pressure is necessary to overcome forces related to surface tension. A sufficiently long application of the critical opening pressure is necessary to ventilate all alveoli despite different retraction forces in the airways. All of this can be accomplished using pressure control ventilation.[19]

Many authors have suggested that peak pressures greater than 50 cm H_2O accentuate lung damage. One author suggests that peak pressure may be even more deleterious than high F_{IO_2}.[19] Not any one reason can be identified as the major contributor of damage. Most authors believe that barotrauma can be or is caused by many influences. The facts are simple—As pressures go up on our ventilators so does the risk of barotrauma.

With all of the confusion about barotrauma certain findings can be certainly identified:

- Uneven volumetric expansion of the lung may cause barotrauma.
- High pressures associated with uneven expansion can cause further damage such as emphysema, interstitial fibrosis, pneumothorax,and pneumomediastinum.
- Cardiovascular side effects can be pronounced when using high pressures and high PEEP.

A mode of ventilation exists that will allow for better distribution of gas, more even ventilation, and improved oxygenation with less peak pressure/PEEP. By using pressure-control ventilation early in the patient's clinical course perhaps further lung damage can be avoided.

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PIP and Barotrauma: A Response to Chatburn

Like Chatburn,[1] I too have read with interest (and occasional bemusement), the various points of view, theories and misconceptions that have been generated in the Letters section in response to the Kacmarek and Hess editorial on pressure-controlled ventilation (PCV).[2] I agree with and admire the clarity of Chatburn's explanation of the fundamental differences between the exponentially decelerating flow pattern in PCV and, the preprogrammed flow patterns of volume-controlled ventilation (VCV).[1] During PCV, the decreasing contribution of airway resistance (R_{aw}) to peak inspiratory pressure (PIP) as inspiration progresses from initial to maximum volume was described by Mapelson[3] in 1959. PCV was more theoretical than practical until the advent of the Servo 900-C (1980); so this simple relationship was overlooked by most practitioners in the ensuing years. (Even among the more erudite clinicians at our institution, this concept is sometimes misunderstood.)

In describing other factors that influence PIP and dynamic distribution of ventilation, Chatburn has oversimplified the physiology present in acute severe lung injury such as adult respiratory distress syndrome (ARDS). In doing so, he has underestimated the importance that PIP may play in barotrauma, even in the presence of a normal tidal volume (V_T) to the lung as a whole.

How PIP May Contribute to Barotrauma

First, I agree that it is primarily hyperinflation that causes barotrauma[4,5] but, more specifically, it is hyperinflation to a specific region that exceeds the elastic limits of those tissues and causes eventual rupture. Other variables have been implicated, though, including shear forces, mean airway pressure, surfactant depletion, tissue fragility, duration of ventilation, and PIP.[4]

To understand how (in the presence of normal V_T) localized hyperinflation occurs, and is exacerbated by high PIP, it is necessary to review how local differences in R_{aw} and lung compliance (C_L) affect the distribution of ventilation. In a healthy lung, the distribution of ventilation is relatively uniform at normal respiratory rates, and normal inspiratory- to expiratory-time ratios, I:E.[6] This results in relatively uniform pressure and volume distribution among alveoli.

In profound lung injury (such as ARDS) this is certainly not the case. In animal studies, in which surfactant washout and mechanical ventilation were used to induce severe acute lung injury (similar to the type seen in ARDS or idiopathic, [or infant] respiratory distress syndrome, IRDS), exceedingly nonuniform areas of injury occurred.[7] Histologic examination of the tissues revealed poorly expanded hyaline-membrane- and fluid-filled alveoli along side of well expanded and even hyperinflated alveoli. The airways leading to these poorly expanded alveoli sometimes had desquamation and necrosis of epithelium. Computerized axial tomography (CAT) scans of patients with ARDS also reveal similar features—"marked heterogeneity in the roentgenographic density of the lung."[4] These pathologic structural alterations result in differences in volume distribution among

regions of the lung. This dynamic maldistribution of tidal volume is increased with shorter inspiratory times, wider variations in R_{aw}, C_L, and peak pressures. These interactions (first described by Otis et al[6]) also have applicability in VCV, although they are more commonly associated with pressure ventilation.

The lung can be thought of as a nearly infinite number of parallel paths consisting of conducting airways and alveoli through which gas may travel. The rate at which any pressure change is transmitted from the airway threshold to the alveolus is a function of the product of R_{aw} and alveolar compliance (C_A). This product is the time constant (tau, τ) for that path. If the τ is small, pressure equilibration is rapid; if the τ is large, pressure equilibration is slow. Ninety-five percent equilibration in pressure occurs after three τ. (This is only the most cursory of explanations of the time constant model of the lung, for a comprehensive review see References 6 and 8.)

A consequence of this theory is that as long as significant flow exists in the lung, widely varying τ will result in large interregional differences in pressure at any given time. If very high driving pressures (PIP) are present, these differences will be exaggerated.

Because the volume of any alveolus is the product of pressure and compliance [that is, (cm H_2O)(mL/cm H_2O) = mL], those alveoli that have low-resistance airways leading to them and normal C have potentially large changes in volume in situations in which PIP is allowed to rise precipitously (even briefly). *This will happen even in the presence of a normal V_T to the lung as a whole!*

VCV Compared to PCV

In VCV, PIP fluctuates with changes in large and small airway resistances either due to changes in bronchial tone or secretion accumulation. Changes in patient position, splinting, coughing, breathing out of phase with the ventilator ("bucking the vent"), and the addition of medication nebulizers inline also increase PIP. If the emergency relief pressure is significantly higher than the normal PIP, then large fluctuations in alveolar volumes may occur transiently in alveoli with short τ. This may lead to barotrauma. To minimize this risk, relief pressure limits should be very close to the normal PIP for that patient at that time. This frequently doesn't happen in clinical practice because of the annoyance of alarms sounding every few minutes.

In PCV, the changes mentioned may cause decreases in V_T for one or more breaths, depending on the particular circumstances. Because the maximum pressure is limited to the pressure necessary to produce the proper V_T under normal circumstances, the transient drastic increases in volume that may occur in some alveoli during VCV do not occur in PCV.

There are other complexities to PCV that may contribute to barotrauma if the mode is not properly understood and patient monitoring is inadequate. If C_L improves and the pressure-control level is not decreased commensurately, dangerous increases in V_T may occur. Another potential problem can occur when dialed-in, or set, inspiratory time (t_i) is shorter than three τ for the lung (as a whole) and R_{aw} suddenly drops. Under such circumstances, a sudden increase in V_T may also occur. All of these problems are easily controlled by a proper understanding of the physiology of PCV and proper monitoring.

Contrary to what Chatburn espouses, I believe that fluctuations in PIP itself may contribute to barotrauma, and PCV, with or without inverse I:E, has a unique potential for limiting this problem.

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Mr Chatburn Responds to Mr Jones

I am pleased that my letter to the editor[1] has stimulated some thoughtful response. First, let me reiterate the conclusion of my earlier analysis: "the concept that barotrauma is caused by pressure without regard to lung mechanics is erroneous. Hence, the idea of decreasing the risk of barotrauma by switching from volume-controlled to pressure-controlled ventilation in an attempt to lower PIP, without regard to changes in the delivered V_T is invalid." In other words, an observed increase in peak inspiratory airway pressure (PIP) during volume-controlled ventilation does not necessarily mean that the risk of barotrauma has increased. On the other hand, a deliberate decrease in PIP during pressure-controlled ventilation does not mean that the risk of barotrauma will decrease. In my letter, these conclusions were based on the equation of motion for a single-compartment model of the lungs.

Mr Jones brings up the important point that a single compartment does not adequately describe the behavior of diseased lungs. This has been the topic of recent research.[2,3] Use of a two-compartment model, for instance, is clinically relevant but the analysis is much more complicated as we will see.

Otis et al,[4] using a two-compartment model, have provided an analysis for pressure-controlled ventilation with a sinusoidal waveform. Mr Jones[5] interprets their work to mean that "(The) dynamic maldistribution of tidal volume is increased with shorter inspiratory times, wider variations in R_{aw}, C_L and peak pressures." and "as long as significant flow exists in the lung, widely varying tau (ie, time constants) will result in large inter-regional differences in pressure at any given time. If very high driving pressures (PIP) are present, these differences will be exaggerated." From this Mr Jones concludes that "those alveoli that have low resistance airways and normal C will have potentially large changes in volume in situations where PIP is allowed to rise precipitously". It is not clear what he means by PIP being allowed to rise precipitously, but I assume that he is referring to volume-controlled ventilation.

Mr Jones then illustrates some situations in which PIP increases precipitously during volume-controlled ventilation and surmises that "large fluctuations in alveolar volumes may occur transiently in short τ alveoli.", possibly leading to barotrauma. He finally concludes that contrary to my opinion, "fluctuations in PIP itself may contribute to barotrauma and (pressure controlled ventilation) has a unique potential for limiting this problem."

Mr Jones is on the right track but I believe that there may be problems with his interpretation of the work by Otis et al.[4] First, I do not believe that study can be directly applied to the topic I mentioned in the first paragraph because they used pressure-controlled ventilation with a sinusoidal waveform. Their results are applicable to high frequency ventilation or, perhaps, to spontaneous ventilation. Our discussion relates to pressure- or volume-controlled ventilation with rectangular waveforms.

Second, Otis et al[4] stated that "In ... a network consisting of two or more separate pathways in parallel, the distribution of the overall flow in the separate pathways and the timing of the flow events depends on the distribution of the impedance of the separate pathways." If two parallel lung units have the same impedance, they will have the same time constants and will both experience the same flow pattern. However, if they have different impedances, there are two cases: either the time constants are the same and the distribution of ventilation is the same as if the impedances were the same, or the time constants are different, in which case the flow into the two lung units will be different. This is a result that follows from basic electric circuit analysis when pulmonary structures are modeled as electric circuit components. The point of Otis et al's work was to show that the effective compliance and resistance of the *total* respiratory system were frequency dependent. This happens when there is a nonuniform distribution of time constants among lung units. But this is beside the point—we are interested in maldistribution of ventilation among lung units not frequency dependence of mechanical properties.

To answer Mr Jones' concerns, we must first postulate an appropriate model of the respiratory system. Such a model is shown in Figure 1. I will apply the techniques of electronic circuit analysis to answer two general questions:

1. What factors affect the distribution of ventilation between the two lung units?
2. What factors affect the pressure and flow to the system as a whole?

I will answer these questions for both pressure-controlled and volume controlled ventilation with rectangular waveforms. From these theoretical results we should be able to deduce some clinically relevant principles of mechanical ventilation.

Figure 1 illustrates the basic analytical approach. It shows two parallel lung units that could represent anything from whole lungs to single alveoli. Each lung unit is composed of a compliance connected in series with a resistance. The parallel lung units are connected in series with an upper airway resistance (which might represent anything from an endotracheal tube to an alveolar duct) and a chest wall compliance (which includes the compliance of

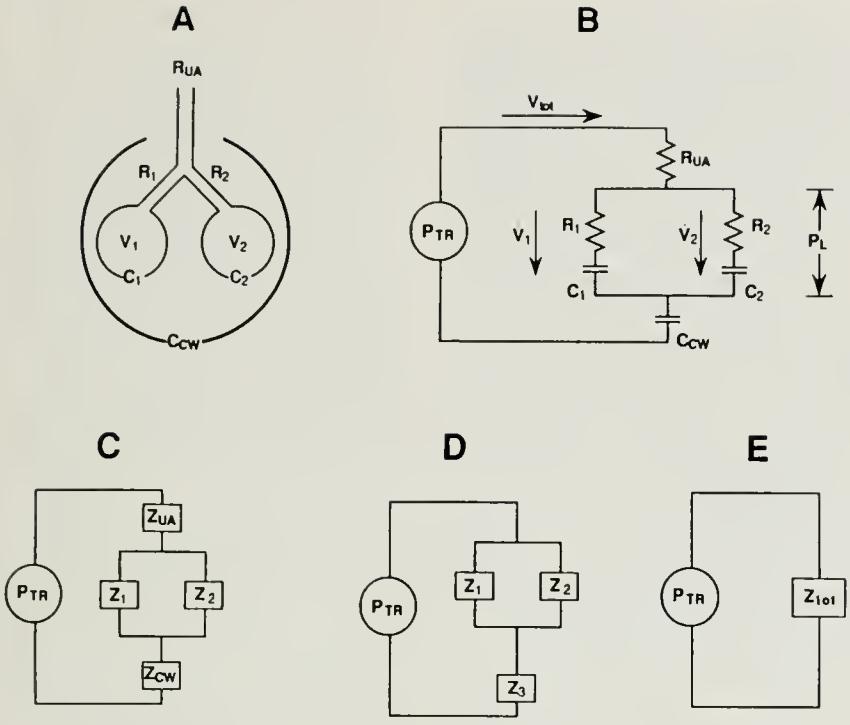

Fig. 1. This figure illustrates the process of converting a graphic model of the lungs (A) to an equivalent electronic circuit (B). The electronic circuit is further simplified by expressing resistances (R) and compliances (C) and combinations of resistance and compliance in terms of impedances (Z). P = pressure, $\dot{V}$ = flow, UA = upper airway, CW = chest wall, TR = transrespiratory, and L = lung.

the diaphragm). This model assumes that all resistances and compliances remain constant throughout the ventilatory cycle. This probably holds true with normal tidal volumes and flows for areas near the alveolar level where turbulence (which would cause resistance to be nonlinear) is unlikely.

Each individual compliance and resistance has its own value of impedance. However, to simplify the analysis, the impedances are combined. That is, we can define two impedances to represent the two parallel lung units and a third to account for the upper-airway resistance combined with chest-wall compliance. Going a step further, we can combine all into one equivalent total impedance.

Each of the three impedances (Z) in Figure 1D has the form of

$$Z = \frac{s\tau + 1}{sC} \quad (1)$$

where

$$\tau = RC \quad (2)$$

and the total impedance is:

$$Z_{tot} = \frac{s^2A_1 + sA_2 + A_3}{s^2A_4 + sA_5} \quad (3)$$

where

$$A_1 = \tau_1\tau_2C_3 + \tau_1\tau_3C_2 + \tau_2\tau_3C_1 \quad (4)$$

$$A_2 = (\tau_1 + \tau_2)C_3 + (\tau_1 + \tau_3)C_2 + (\tau_2 + \tau_3)C_1 \quad (5)$$

$$A_3 = C_1 + C_2 + C_3 \quad (6)$$

$$A_4 = C_3(\tau_1C_2 + \tau_2C_1) \quad (7)$$

$$A_5 = C_3(C_1 + C_2) \quad (8)$$

and s is a complex variable involving $\sqrt{-1}$ and frequency.[6]

Having defined the model in terms of impedance, we can describe the factors affecting pressure and flow throughout the model by making use of Ohm's law in the form

$$P = \dot{V}Z \quad (9)$$

where P = pressure and $\dot{V}$ = flow. We will also make use of the fact that by definition, two parallel components experience the same pressure drop and two or more series components share the same flow.[7] By substituting the desired mathematical expression for the driving function (ie, equations that describe either rectangular pressure or flow waveforms), we can use the LaPlace transform to solve Equation 9 to get either pressure or flow as a function of time. Specifically, we want the ratio of $\dot{V}_1$ to $\dot{V}_2$. This will make evident the factors that cause uneven distribution of ventilation, which is indicated by a ratio $\neq 1$.

Pressure-Controlled Ventilation

During pressure-controlled ventilation with a rectangular pressure waveform, the transrespiratory pressure stays constant throughout the inspiratory phase. However, the pressure difference across the lung units changes exponentially. The resulting flows into the two lung units is given by

$$\frac{\dot{V}_1}{\dot{V}_2} = \left(\frac{C_1}{C_2}\right)\frac{(e^{S_1 t} - e^{S_2 t}) + \tau_2(S_1 e^{S_1 t} - S_2 e^{S_2 t})}{(e^{S_1 t} - e^{S_2 t}) + \tau_1(S_1 e^{S_1 t} - S_2 e^{S_2 t})} \quad (10)$$

where

$$S_1, S_2 = \frac{-A_2 \pm \sqrt{A_2^2 - 4A_1A_3}}{2A_1} \quad (11)$$

Of special interest are the values of Equation 10 at t = 0+ and t = infinity (ie, for the very beginning of inspiration and at steady state, respectively). For t = 0+, Equation 10 reduces to:

$$\frac{\dot{V}_1}{\dot{V}_2} = \frac{R_2}{R_1} \quad (12)$$

For t = infinity, Equation 9 becomes

$$\frac{\dot{V}_1}{\dot{V}_2} = \frac{C_1}{C_2}\left(\frac{1 + \tau_2 S_1}{1 + \tau_1 S_1}\right) \quad (13)$$

where

$$|S_1| < |S_2| \quad (14)$$

In the special case where $\tau_1 = \tau_2$, Equation 10 becomes

$$\frac{\dot{V}_1}{\dot{V}_2} = \frac{C_1}{C_2} \quad (15)$$

for all t. It follows that if $C_1 = C_2$:

$$\frac{\dot{V}_1}{\dot{V}_2} = 1 \quad (16)$$

Notice that the distribution of ventilation between the two lung units does not depend on the driving pressure. Thus, Mr Jones' statement that high driving pressures exaggerate maldistribution of inter-regional pressures is not correct. His statement that short inspiratory times cause maldistribution may or may not be correct depending on the relative values of resistance and compliance. If, for example, the resistances are unequal and the compliances are equal, then a shorter inspiratory time will result in a greater inequity of flow between the lung units (ie, a ratio farther from one). But if the resistances are equal and the compliances are unequal, shorter inspiratory times will result in more even distribution of ventilation (ie, a ratio closer to one).

The total flow through the system is

$$\dot{V}_{tot} = \frac{P_{TR}}{A_1}(K_1 e^{s_1 t} + K_2 e^{s_2 t}) \quad (17)$$

where

$$K_1 = \frac{C_3(\tau_1 C_2 + \tau_2 C_1)s_1 + C_3(C_1 + C_2)}{S_1 - S_2} \quad (18)$$

$$K_2 = \frac{C_3(\tau_1 C_2 + \tau_2 C_1)s_2 + C_3(C_1 + C_2)}{S_2 - S_1} \quad (19)$$

If any of the compliances decrease or any of the resistances increase, the total impedance will increase and total flow (and tidal volume) will decrease.

Volume-Controlled Ventilation

During volume-controlled ventilation with a rectangular flow waveform, flow into the two lung units is

$$\frac{V_1}{V_2} = \frac{(\tau_1 + C_1R_2) + (\tau_2 - \tau_1)e^{-t/K_3}}{(\tau_2 + C_2R_1) + (\tau_1 - \tau_2)e^{-t/K_3}} \quad (20)$$

where

$$K_3 = \frac{C_2\tau_1 + C_1\tau_2}{C_1 + C_2} \quad (21)$$

For t = 0+, Equation 20 reduces to

$$\frac{\dot{V}_1}{\dot{V}_2} = \frac{R_2}{R_1} \quad (22)$$

For t = infinity, Equation 20 yields:

$$\frac{\dot{V}_1}{\dot{V}_2} = \frac{C_1}{C_2} \quad (23)$$

In the special case where $\tau_1 = \tau_2$,

$$\frac{\dot{V}_1}{\dot{V}_2} = \frac{C_1}{C_2} \quad (24)$$

for all t. Then if $C_1 = C_2$:

$$\frac{\dot{V}_1}{\dot{V}_2} = 1 \quad (25)$$

Just as peak pressure does not affect the distribution of flow during pressure-controlled ventilation, neither peak pressure nor peak flow affects the distribution of flow during volume-controlled ventilation.

Transrespiratory pressure is

$$P_{TR} = F\left[(R_3 + D_1) + \left(D_2 + \frac{1}{C_3}\right)(t) + D_3 e^{-t/K_3}\right] \quad (26)$$

where F is the peak inspiratory flow rate and

$$D_1 = \frac{\tau_1 C_1 + \tau_2 C_2}{(C_1 + C_2)^2} \quad (27)$$

$$D_2 = \frac{1}{C_1 + C_2} \quad (28)$$

$$D_3 = \frac{-C_1C_2(\tau_1 - \tau_2)^2}{(C_1\tau_2 + C_2\tau_1)(C_1 + C_2)^2} \quad (29)$$

If any of the compliances decrease or any of the resistances increase, the total impedance will increase and peak inspiratory pressure will increase.

Conclusions

An interpretation of the above analysis is far from being intuitively obvious. However, we can see that the distribution of ventilation between parallel lung units is a function of the resistances, compliances, and time constants, not simply of time constants alone. Factors such as peak inspiratory pressure and peak flow do not affect the distribution of ventilation. Inspiratory time has a variable effect depending on the relative values of the resistances and compliances.

These results support my contention that thinking only in terms of PIP is misleading. For example, during volume-controlled ventilation, PIP will increase *without* leading to a maldistribution of ventilation in:

Case 1: both C_1 and C_2 decrease an equal amount.

Case 2: both R_1 and R_2 increase an equal amount.

Case 3: compliance of the chest wall and/or diaphragm decreases (eg, increase in muscle tone due to removal of paralysis, subcutaneous emphysema, or compression of diaphragm by abdominal contents).

Case 4: upper-airway resistance increases.

Case 5: forces applied by the the patient's ventilatory muscles.

During volume-controlled ventilation, an increase in the resistance and/or a decrease in the compliance of one lung unit leads to an increase in volume delivered to the other and an increase in PIP. In this case, an increase in PIP may correspond to an increased risk of barotrauma if one lung is overexpanded, as Mr Jones suggests. However, Cases 1-4 contradict the conclusion that an increase in PIP of *itself* indicates overexpansion.

To illustrate my point, I will use Mr Jones' own examples. Changes in airway resistance due to bronchial tone or secretions are examples of Cases 2 or 4 above. Changes in patient position may result in Cases 1-3 above. Splinting, coughing, and breathing out of phase with the ventilator are examples of Case 5. In all of these cases, under- rather than overexpansion of the two lung units is more likely due to more gas being compressed in the patient circuit.

However, we have yet to discuss the most interesting of the findings from this brief model study. What we would really like to know is which mode of ventilation is best in terms of the risk of barotrauma. We will assume that barotrauma may occur if one lung unit is likely to overexpand or if one lung unit tends to expand more than the other, causing a build up of stress in the connective tissues between the lung units. Both of these cases would be indicated by a flow ratio $\neq 1$. The farther the value is from one, the more unequal the distribution of ventilation between the units and, we postulate, the greater the risk of barotrauma.

For which mode of ventilation is this more likely? Looking at Equations 11 and 20, we see that at the beginning of inspiration, the distribution of ventilation between lung units is identical for pressure- versus volume-controlled ventilation. But, look at the steady state values. Equations 12 and 21 show that pressure-controlled ventilation results in a ratio farther from one than does volume-controlled ventilation. That is, whenever $\tau_1 \neq \tau_2$, pressure-controlled ventilation will result in a ratio either greater than or less than one by a factor of $(1+ \tau_2 S_1) / (1+ \tau_1 S_1)$. *This means that pressure-controlled ventilation results in a greater maldistribution of ventilation and presumably a greater risk of barotrauma whenever the time constants of the two lung units are different.* This is particularly true when the tidal volumes during pressure-con-trolled ventilation are matched to those during volume-controlled ventilation to maintain the same P_{aCO_2}. This result will no doubt surprise those proponents of PCIRV who preach that it reduces the risk of barotrauma. It surprises me. I had only intended to show that switching to pressure-controlled ventilation does not necessarily reduce the risk of barotrauma, not that it could actually increase it.

Of course, we must bear in mind the limitations of any model study. For one thing, even a two-compartment model is a gross oversimplification of the respiratory system. It does not, for example, take into account the compliance of the airways or the resistance of the lung tissues. Nor does it account for any nonlinear behavior of resistance or compliance. Nevertheless, this analysis should provide an impetus for clinical studies of either unilateral lung disease or disease that results in a nonhomogeneous distribution of pulmonary mechanics.

I thank Mr Jones for stimulating this discussion. To my knowledge, such an analysis has never before been published.

and to Mr Reynolds

My response to Mr Reynolds is simpler because he gives no rationale for his belief that "pressure does play an extremely important role in barotrauma," and "it is not the 'normal tidal volume' that plays the major role in barotrauma but it is the higher peak and PEEP pressure that causes further lung damage." These statements are defended only by a list of references.[8-12] But most of these references do not address the issue. Mead et al[11] presented a theoretical analysis of lung interdependent forces that did not include a discussion of mechanical ventilating pressures. Robertson et al[9] reported results of parenchymal distortions due to the application of a force,

using a metal rod, to the surface of excised lungs. Hylkema et al[10] measured compliance at different tidal volumes during volume-controlled ventilation and concluded that ventilator settings should be chosen to place the patient's lungs on the steepest part of the pressure-volume curve.

None of these studies addressed the maldistribution of ventilation among lung units with different impedances nor did they examine the relationship of PIP to barotrauma. Dreyfus et al[12] and Kolobow et al[8] performed studies in which animals were ventilated with either low or high tidal volumes and showed that high tidal volumes were associated with lung damage. Dreyfus et al[12] did not report measured volumes. Kolobow et al[8] compared volume-controlled ventilation (at V_T = 10 mL/kg and PIP = 15-20 cm H_2O) with pressure-controlled ventilation (at V_T = 50-70 mL/kg and PIP = 50 cm H_2O). They gave no reason for switching from volume control to pressure control.

Despite the fact that both studies (and those they reference that preceded them) increased both tidal volume and pressure, these researchers arbitrarily chose to state their results in terms of high pressures causing damage rather than high volumes. Yet Kolobow et al[8] state in their discussion that "We believe the major component of injury in healthy lungs ventilated suddenly at a PIP of 50 cm H_2O stems from overinflating airway structures at well beyond the maximal lung volume." Thus barotrauma was caused by volumetric expansion beyond the lung's elastic limit, which is what I said in my original letter.[1]

Why did Dreyfus et al[12] and Kolobow et al[8] and previous researchers state their findings in terms of airway pressure? After doing some detective work, I think I know why. According to Kolobow et al,[8] "Greenfield and co-workers were the first to show lungs damaged after MV for 2 hr at an elevated PIP." Looking up Greenfield's 1964 study, we find the conclusions stated as follows: "Overinflation of the lungs results in depletion or alteration in surfactant which is essential to the maintenance of expanded alveoli at end-expiratory pressure. Prolonged positive pressure at normal pressure and volume does not alter surfactant and did not result in atelectasis in this study."[13] Notice that Greenfield et al talked in terms of "overinflation" or normal pressure and volume. So why did Kolobow et al ignore the implication of volume and simply talk in terms of PIP when referring to previous studies and their own study hypothesis? Perhaps it is because Greenfield et al did not report tidal volumes, although they used volume-controlled ventilation with a Mörch ventilator. In 1970, Barsh et al[14] performed a similar study using a Harvard pump but also did not report tidal volumes. Then came Webb and Tierney[15] in 1974, using a Harvard pump and reporting both pressures and volumes. However, they too cast their hypothesis in terms of pressure alone for no obvious reason. Their conception of "high inspiratory positive pressure breathing" was to increase the tidal volume (for rats) from a baseline of about 3 mL to 7 mL and then 10 mL, without PEEP. Their discussion contained such statements as "The mechanism of alveolar edema formation during HIPPB...may be related to the increased surface forces that develop during ventilation of excised lungs with large Vt." and "Several studies have shown that pulmonary edema develops in the open-chest animal during ventilation with relatively large Vt, whereas ventilation of intact control animals with the same Vt and frequency induced no abnormalities. We conclude that ventilation-induced alveolar edema depends on a high (PIP) in conjunction with a low end-expiratory volume." Throughout the discussion they jump back and forth between talking about large tidal volumes and large inspiratory pressures for no apparent reason and without a unifying theoretical framework.

So it seems to me that researchers who talk of PIP in conjunction with barotrauma instead of talking in terms of tidal volumes and optimizing pressure-volume curves are just lazy. They are arbitrarily simplifying and thus confusing the issue. Unfortunately, some readers may parrot their words without understanding their implications. This leads to conclusions like "The facts are simple...as pressures go up on our ventilators so does the risk of barotrauma." I have given several common scenarios in which pressures go up and the risk of barotrauma is unaffected or decreased.

Mr Reynold's letter tries to sell us on the benefits of pressure-controlled ventilation by summarizing what he believes are the important findings about barotrauma: (1) *uneven volumetric expansion of the lung may cause barotrauma*—yes, but pressure-controlled ventilation does not prevent uneven expansion, and I have provided theoretical data that suggest that pressure-controlled ventilation may be inferior to volume-controlled ventilation in this regard; (2) *high pressures associated with uneven expansion can cause damage*—high pressure gradients between alveoli and perivascular sheaths not high ventilating pressures per se cause barotrauma, and uneven expansion can occur at low ventilation pressures; (3) *cardiovascular side effects can be pronounced when using high pressures and PEEP*—this is beside the point but it should be remembered that, in general, pressure-controlled ventilation results in higher mean airway pressure than volume-controlled ventilation at the same tidal volume and PEEP.[1]

increasing the risk of cardiovascular problems. My rebuttal to these points should not be interpreted as a rejection of pressure-controlled ventilation—indeed, I think it offers advantage in some situations.[16] My objective was to help people to understand the principles and terminology involved and avoid the trap of believing advertising propaganda.

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References

Use of References: References are used to support statements of fact, to indicate sources of information, or to guide readers to further information. Be careful to make clear in the text the reason for a specific citation (ie, do not imply support of a statement of fact by citing a reference that simply addresses the issue). Cite only sources that have actually been consulted and evaluated by the authors. Cite only ***published or accepted*** material. Cite original articles in preference to textbooks, review articles, abstracts, editorials, or letters. Avoid citing abstracts more than 3 years old and make every effort to determine whether an abstract has been subsequently published as a full-length paper. Avoid citing non-English language sources. When citing from a book, specify the page numbers unless you are citing the entire book. If you cite a paper that has been accepted but not yet published ("in press"), provide a copy of the paper to the Editor when you submit your manuscript.

Do not cite unpublished observations as references. Instead, identify written (not oral) communications in parentheses in the text, giving the writer's name and location and the date of the communication. Information from manuscripts submitted but not yet accepted should be cited in the text (in parentheses) as "unpublished observations."

Citing References in the Text: The first reference you cite is Reference 1, the next is Reference 2, etc. After the first citation of a reference, use its original number if you cite it again later in the paper. Cite references by superscript, full-size, arabic numerals. Do not enclose in parentheses. If a citation numeral is located at the end of a phrase or sentence, place the numeral after (outside) the comma, semicolon, or period—not before (inside) it.Avoid citing references at the end of a phrase or sentence if they pertain only to internal parts of the phrase or sentence; instead, cite them at the pertinent places within the phrase or sentence.

Listing References: Starting on a new page after the text, list the references in numerical order. Do not employ "op cit" or "ibid." Type references double-spaced, using the styles of the examples given hereafter. List all authors (do not use "et al"). In titles of articles and books, capitalize only first words and proper names. Abbreviate journal names as in Index Medicus. Spell out in full the names of less well known or nonindexed journals and periodicals If the cited item is an abstract, editorial, or letter, identify it as such in parentheses following the item's title. Provide both first and last complete page numbers. Do not leave spaces between dates and volume and page numbers. Obtain authors' names, article and book titles, dates, and volume and page numbers from the *original* cited articles and books, not from other articles' reference lists, which often are inaccurate. Examples of correct reference listings follow (these are single-spaced here but must be *double-spaced* in a manuscript).

Article in a journal carrying pagination throughout volume:

1. Shepherd KE, Johnson DE. Bronchodilator testing: an analysis of paradoxical responses. Respir Care 1988; 33:667-671.

Article in publication that numbers every issue beginning with Page 1:

2. Bunch D. Establishing a national database for home care. AARC Times 1991:15(Mar):61,62,64.

Corporate author journal article:

3. American Association for Respiratory Care. Criteria for establishing units for chronic ventilator-dependent patients in hospitals. Respir Care 1988;33:1044-1046.

Article in journal supplement: (Journals differ in their methods of numbering and identifying supplements. Supply sufficient information to allow retrieval.)

4. Reynolds HY. Idiopathic interstitial pulmonary fibrosis. Chest 1986;89(3, Suppl):139s-143s.

Abstract in journal: (Abstracts are not strong references. Abstracts more than 3 years old should not be cited. When cited, abstracts should be identified as such.)

5. Stevens DP. Scavenging ribavirin from an oxygen hood to reduce environmental exposure (abstract). Respir Care 1990;35:1087-1088.

Editorial in journal:

6. Rochester DF. Does respiratory muscle rest relieve fatigue or incipient fatigue? (editorial). Am Rev Respir Dis 1988;138:516-517.

Editorial with no author given:

7. High frequency ventilation (editorial). Lancet 1991; 1:706-708.

Letter in journal:

8. Smith DE, Herd D, Gazzard BG. Reversible bronchoconstriction with nebulised pentamidine (letter). Lancet 1988;2:905.

Paper accepted but not yet published:

9. Hess D. New therapies for asthma. Respir Care (year, in press).

Personal author book: (Specific pages should be cited whenever possible.)

10. Nunn JF. Applied respiratory physiology. New York: Appleton-Century Crofts, 1969.

Note: To specify pages in a book, place a colon after the year and then list the page(s). Examples: 1969:85 (one page), 1969:85-95 (series of contiguous pages), 1969:85,95 (separated pages).

Corporate author book: (Specific pages should be cited whenever possible.)

11. American Medical Association Department of Drugs. AMA drug evaluations, 3rd ed. Littleton CO: Publishing Sciences Group, 1977.

Book with editor(s): (Specific pages should be cited whenever possible.)

12. Guenter CA, Welch MH, editors. Pulmonary medicine. Philadelphia: JB Lippincott, 1977.

Chapter in book: (Specific pages should be cited whenever possible.)

13. Pierce AK. Acute respiratory failure. In: Guenter CA, Welch MH, editors. Pulmonary medicine. Phildelphia: JB Lippincott, 1977:171-223.

Newspaper article:

14. Rensberger B, Specter B. CFCs may be destroyed by natural process. The Washington Post 1988 Aug 7;Sect A:2(Col 5).

Dictionary or similar reference:

15. Pneumohemopericardium. Dorland's illustrated medical dictionary, 26th ed. Philadelphia: WB Saunders, 1981: 1038.

Tables: Use tables to display information, compare data, or show trends. Start each table on a separate page. Do not construct a table with fewer than four lines (rows) of data (instead, put the data in the text). Avoid more than 8 columns across.

Number tables as Table 1, Table 2, etc, consecutively in the order of their first mention in the text. Place the number and a ***descriptive*** title above the table (not on a separate page). Give each column a brief heading. Place explanatory matter in footnotes, not in the title or column headings. Explain in footnotes all nonstandard abbreviations and symbols used in the table. To key footnotes to the table body, use conventional designations (asterisk, dagger, double dagger, etc) in consistent order, placing them superscript in the table body.

Double-space all elements of tables, including titles, column headings, data, and footnotes. Continue a deep table on following pages. Do not use horizontal or vertical rules. Do not submit tables as photographs, or reduced in size, or on oversize paper. Use the same typeface as in the text. Supply the name and version of any table-building computer program used.

Appendices: Mathematical calculations, documents, and other matter that would clutter the main article can be displayed in appendices. Number them as Appendix 1, Appendix 2, etc, and refer to them in the text. Give each appendix a descriptive title and type it double-spaced throughout.

Illustrations: Graphs, line drawings, photographs, and radiographs are called figures. Use only illustrations that clarify and augment the text. Number them consecutively as Fig. 1, Fig. 2, etc, according to the order in which they are first mentioned in the text. Figures for publication must be of professional quality, but rough sketches may accompany the submitted manuscript, with final figures to be prepared after review. Figures need not be photographic reproductions. Clear, clean laser-printer-generated figures are acceptable (121-144 dpi). Remember that originals that are roughly 7 × 9 inches will be reduced to less than 50% (3 × 4 in) and originals with a horizontal dimension of 9 in will be reduced to less than 33%. Photographs must be glossy 5 × 7 to 8 × 10-inch black and white prints, unless color is essential. (If color is essential, consult the Editor to learn whether negatives, transparencies, or prints are required.) In reports of animal experiments, use schematic drawings, not photographs. A letter of consent must accompany any photograph in which a possibility of identification of a person exists; masking the eyes is not sufficient. Lettering and numerals must be neat, uniform in size and style, and large enough to remain legible when downsized for publication. Do not place titles and detailed explanations on figures; put such information in the figure legends. Identify each figure on the back with a stick-on label showing figure number, an arrow indicating the top, and an abbreviated manuscript title. ***Omit author's name.*** Cover label with clear tape so ink will not smudge other prints. Do not use staples or paper clips, and do not write heavily on the backs of prints.

Radiographs: If possible, submit radiographs as full-size copies of films, not as prints. Prints may be acceptable, but full-size films are preferable in order to display better detail in published figures. Be sure all figures are cited in the text. If any figure has been published before, include copyright-holder's written permission to use it.

Figure Legends: Its legend should, to the extent possible, make a figure understandable without referring the reader to the text. Type figure legends double-spaced, on a separate page, as Fig. 1, Fig. 2, etc. When symbols, arrows, numbers, or letters are used to identify parts of a figure, identify and explain each part clearly in the legend. In photomicrographs, explain the internal scale and method of staining. If a figure has been published before, acknowledge the original source in its legend (permission must be obtained prior to use, of course).

Units of Measurement: Give measurements of length, height, weight, and volume in metric units appropriately abbreviated. Give temperatures in degrees Celsius. Give blood pressures in millimeters of mercury (mm Hg). Report hematologic and clinical-chemistry measurements in conventional metric system and in SI units (International System of Units). Show gas pressures (including blood gas tensions) in torr. List SI equivalent values, when possible, in brackets following non-SI values—for example, "PEEP, 10 cm H_2O [0.981 kPa]." For conversion to SI, see RESPIRATORY CARE 1988;33:861-873 (Oct 1988) and 1989;34:145 (Feb 1989).

Arithmetic: Carefully double-check all arithmetic before submitting the paper. Accuracy is the author's responsibility; errors are common!

Abbreviations and Symbols: Use standard abbreviations and symbols. Avoid creating new abbreviations. Avoid all abbreviations in the title and unusual abbreviations in the abstract. Use an abbreviation only if the term occurs several times in the paper. Write out the full term the first time it appears, followed by the abbreviation in parentheses. Thereafter, employ the abbreviation alone. Never use an abbreviation without defining it. Standard units of measurement can be abbreviated without explanation (eg, 10 L/min, 15 torr, 2.3 kPa). If you employ a great many abbreviations and symbols, provide a double-spaced list of them, with their definitions, in alphabetical order.

Please use the following forms: cm H_2O (not cmH_2O), f (not bpm), L (not l), L/min (not LPM, l/min, or lpm), mL (not ml), mm Hg (not mmHg), pH (not Ph or PH), $p > 0.001$ (not $p>0.001$), s (not sec), S_{pO_2} (pulse oximetry saturation).

Computer Diskettes: A manuscript may be submitted on a Macintosh or IBM-compatible diskette. **Macintosh documents on 3.5 in. diskettes written in Microsoft Word versions 4.0 and 5.0 are preferred. Acceptable programs are** MacWrite, Macintosh Works, Word for Window version 3.0; WindowsWrite; WordPerfect versions 4.1, 4.2, 5.0; WordStar releases 3.3, 3.45, 4.0.

Label each diskette with date; author's name; name of word-processing program and version used to prepare documents; and filename(s). If not enough space is available, list contents on disk jacket or an attached note. Do not write on a diskette except with a felt-tipped pen.

Tables and figures must be in their own separate files, with software identified.

Together with diskette, supply three hard copies of the manuscript. Do not paperclip a diskette to its hard copy.

Proofreading and In-house Review: Have all authors proofread the manuscript for content accuracy and language. Consider having the manuscript reviewed in-house by colleagues before submitting it.

Submitting the Manuscript

Use the checklist below to make sure the manuscript is ready for mailing. Mail three copies of the manuscript and figures to **RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229-4593.** Do not Fax manuscripts. Protect figures with cardboard to prevent bending. A computer diskette submission must be accompanied by the requisite three hard copies. Keep a copy of the manuscript and figures in your files in case of loss. You will be sent an acknowledgment that your manuscript has been received.

Cover Letter: The manuscript must be accompanied by a covering letter signed by all the authors. The letter must specify the intended publication category and, when there are two or more authors, state that "We, the undersigned, have all participated in the work reported, proofread the accompanying manuscript, and approved its submission for publication."

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Author's Checklist:

1. Does paper fit a listed publication category?
2. Does the cover letter meet specifications?
3. Is the title page complete?
4. **Is double-spacing used throughout entire manuscript?**
5. Are all pages numbered in upper-right corners?
6. Are paragraphs indented 5 spaces?
7. Are all references, figures, and tables cited in the text?
8. Are references typed in requested style?
9. Have SI values been provided?
10. Has all arithmetic been checked?
11. Have generic names of drugs been provided?
12. Have necessary written permissions been provided?
13. Have authors' names been omitted from text and figure labels?
14. Have copies of "in press" references been provided?
15. Has manuscript been proofread by all authors?

Calendar of Events

Not-for-profit organizations are offered a free advertisement of up to eight lines to appear, on a space-available basis, in Calendar of Events in RESPIRATORY CARE. Ads for other meetings are priced at $5.50 per line and require an insertion order. Deadline is the 20th of month two months preceding the month you wish the ad to run. Submit copy and insertion orders to: Calendar of Events, RESPIRATORY CARE, 11030 Ables Lane, Dallas TX 75229-4593.

AARC & AFFILIATES

January 22-24 in Clackamas, Oregon. The OSRC presents its Annual Educational Meeting at the Monarch Motor Hotel. Topics cover new trends in neonatal, pediatric, and adult ventilation; ethical issues; National Asthma Educational Program; and hyperbaric medicine. Social events include a bus trip to Mt Hood for an evening of skiing. Contact Mike Taylor at (503) 280-4797.

January 25 in Ruidoso, New Mexico. The NMSRC presents its 3rd Annual Winterfest at the Swiss Chalet Inn. The event features general-interest topics for all respiratory care practitioners. Contact Lee Torres RRT at (505) 624-3556, or write NMSRC, PO Box 35417, Station D, Albuquerque NM 87176-5417.

February 7 in Loma Linda, California. The CSRC (Chapter II), Loma Linda University and Mt San Antonio College present the Second Annual Perinatal/Pediatric NBRC Specialty Exam Review Seminar at Loma Linda University. Contact Cindy Malinowski, Nichol Hall, Loma Linda University, Loma Linda CA 92350. (714) 824-4932.

February 21 in Buena Park, California. Kaiser Permanente and the CSRC (Chapter 4) present a one-day seminar, "Adult Pulmonary Mechanics" at the Buena Park Hotel and Convention Center. Contact Deborah Ortiz at (213) 667-7097 or Linda Sawasaki at (213) 667-8336.

OTHER MEETINGS

January 30-31 in Palm Springs, California. "New Horizons in Sleep Disorders Medicine," a two-day postgraduate course for all health professionals involved in the diagnosis and treatment of sleep disorders, is presented by the California Thoracic Society and the American Sleep Disorders Association. The program focuses on the latest advances in sleep apnea and other sleep disorders and is presented by an internationally acclaimed faculty. Contact the California Thoracic Society, 202 Fashion Ln, Suite 219, Tustin CA 92680. (714) 730-1944.

January 31-February 1 & 2 in Dallas, Texas. Presbyterian Hospital of Dallas presents its 2nd Annual Perinatal/Pediatric Respiratory Care Review Course. This course is designed to assist RCPs in identifying their strengths and weaknesses in preparation for the Perinatal/Pediatric Respiratory Care Specialty Examination. A pretest survey, test-taking skills, specialty lectures, breakout sessions, and an informal review/question & answer session with intense faculty interaction are presented. Contact Ashley Clark at (214) 345-2326.

February 12-14 in Mexico City, Mexico. The Consejo Mexicano de Inhaloterapia presents the 1st International Congress of Respiratory Therapy at the Hotel Paraiso Radisson Perisur. International speakers and exhibits are featured. Contact Dr Hector León Garza at 011-525-588-7386, or fax 011-525-578-8952.

April 4-10 in Miami, Florida. Ventilation Assisted Children's Center, affiliated with the Miami Children's Hospital, sponsors the VACC camp for ventilation-assisted and other technology-dependent children. Application deadline is Jan. 15, 1992. Contact Program Coordinator Cathy Klein at (305) 662-VACC.

April 5-12 on Eastern Caribbean 8-Day Cruise. LIFE Unlimited announces an 8-day cruise for pulmonary patients, friends, and families aboard the SS Seabreeze from Miami to San Juan, St Barts, and St Thomas. Includes all on-board meals, entertainment, prescribed respiratory care services, and private escorted tours. Deadline for paid reservations is Feb. 14 with discounts prior to Jan 3. Take your pulmonary patients on a professionally supervised cruise. Contact Dave Robbins at 1-800-327-5540 or (305) 441-6819.

1992 Call for Abstracts

The American Association for Respiratory Care and its science journal, RESPIRATORY CARE, invite submission of brief abstracts related to any aspect of cardiorespiratory care. The abstracts will be reviewed, and selected authors will be invited to present papers at the Open Forum during the AARC Annual Meeting in San Antonio, Texas December 12-15, 1992. Accepted abstracts will be published in the November 1992 issue of RESPIRATORY CARE. Membership in the AARC is not necessary for participation.

Specifications—READ CAREFULLY!

An abstract may report (1) an **original study,** (2) the **evaluation of a method or device,** or (3) a **case or case series.** Topics may be aspects of adult acute care, continuing care/rehabilitation, perinatology/pediatrics, cardiopulmonary technology, health occupations education, or management of personnel and health-care delivery. The abstract may have been presented previously at a local or regional—but not national—meeting and should not have been published previously in a national journal. The abstract will be the only evidence by which the reviewers can decide whether the author should be invited to present a paper at the Open Forum. Therefore, *the abstract must provide all important data, findings, and conclusions.* Give specific information. Do not write such general statements as "Results will be presented" or "Significance will be discussed."

Essential Content Elements

An **original study** abstract *must* include (1) Introduction: statement of research problem, question, or hypothesis; (2) Method: description of research design and conduct in sufficient detail to permit judgment of validity; (3) Results: statement of research findings with quantitative data and statistical analysis; (4) Conclusions: interpretation of the meaning of the results. A **method/device evaluation** abstract *must* include (1) Introduction: identification of the method or device and its intended function; (2) Method: description of the evaluation in sufficient detail to permit judgment of its objectivity and validity; (3) Results: findings of the evaluation; (4) Experience: summary of the author's practical experience *or* a notation of lack of experience; (5) Conclusions: interpretation of the evaluation and experience. Cost comparisons should be included where possible and appropriate. A **case report** abstract *must* report a case that is uncommon or of exceptional teaching/learning value and must include: (1) case summary and (2) significance of case. Content should reflect results of literature review. The author(s) should have been actively involved in the case and a case-managing physician must be a co-author or must approve the report.

Abstract Format and Typing Instructions

An optical scanner will be used to process abstracts. First line of abstract should be the title. Title should explain content. Type or electronically print the abstract *double-spaced* on *plain white bond paper,* on *one page* only (copier bond is excellent). Do not underline or boldface and insert only one letter space between sentences. Provide a 1-inch margin top and bottom, a 1/2-inch left margin, and an approximate 1/2-inch ragged-right margin. Text submission on diskette is encouraged but must be accompanied by a hard copy. No identification of authors or institutions is to appear on the abstract sheet or in the abstract itself. Make the abstract all one paragraph. Data may be submitted in table form *provided the table width is limited to 55 letter spaces* (ie, letters or numbers plus necessary blank spaces = 55). *No* figures or illustrations are to be attached to the abstract. Type all information required to complete the author information form on the other side of this page. A photocopy of good quality may be used. Standard abbreviations may be employed without explanation. A new or infrequently used abbreviation should be preceded by the spelled-out term the first time it is used. Any recurring phrase or expression may be abbreviated if it is first explained. Check the abstract for (1) errors in spelling, grammar, facts, and figures; (2) clarity of language; (3) conformance to these specifications. An abstract not prepared as requested may not be reviewed. Questions about abstract preparation may be telephoned to the editorial staff of RESPIRATORY CARE at (214) 243-2272.

Deadlines

The mandatory Final Deadline is June 6 (postmark). Authors will be notified of acceptance or rejection by *letter only*— to be mailed by August 15. Authors may choose to submit abstracts early. Abstracts received by March 18 will be reviewed and the authors notified by April 24. Rejected abstracts will be accompanied by a written critique that should in many cases enable authors to revise their abstracts and resubmit them by the final deadline (June 6).

Mailing Instructions

Mail (Do not fax!) 1 copy of the abstract, 1 author information sheet, and a stamped, self-addressed postcard (for notice of receipt) to:

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11030 Ables Lane, Dallas TX 75229

Notices of competitions, scholarships, fellowships, examination dates, new education programs, and the like will be listed here free of charge. Items for the Notices section must reach the Journal 60 days before the desired month of publication (January 1 for the March issue, February 1 for the April issue, etc). Include all pertinent information and mail notice to RESPIRATORY CARE Notices Dept, 11030 Ables Lane, Dallas TX 75229-4593.

Notices

The American Respiratory Care Foundation Announces Literary Awards for 1991

Funded by Allen & Hanburys

$2,000 funded for Best Original Paper published during 1991:

August 1991—An Evaluation of the Usefulness of End-Tidal PCO_2 To Aid Weaning from Mechanical Ventilation following Cardiac Surgery. Dean Hess MEd RRT, Amy Schlottag MSN RN, Bradley Levin MD, John Mathai MD, and William O Rexrode MD (Respir Care 1991;36:837-843)

$1,000 Each for the Four Best Published Papers Based on 1990 OPEN FORUM Presentations:

1. March 1991—Evaluation of Ten Manual Resuscitators across an Operational Temperature Range of -18°C to 50°C. Thomas A Barnes EdD RRT and Deborah L Stockwell (Respir Care 1991;36:161-172)
2. April 1991—Portable Airway-Suction Systems: A Comparison of Performance, by John F Curran RRT, Kevin S Stanek BSEE, and Robert M Kacmarek PhD RRT (Respir Care 1991;36:259-266)
3. November 1991—The Influence of Intravenous Dextrose Infusions on the Carbohydrate Intake of Critically Ill Patients Receiving Nutritional Support. Marcia Kemper BA CRTT and Charles Weissman MD (Respir Care 1991;36:1202-1206)
4. November 1991—Positive-Expiratory-Pressure Mask Therapy: Theoretical and Practical Considerations and a Review of the Literature. Michael J Mahlmeister MS RRT, James B Fink MS RRT, Gale L Hoffman RRT, and Lillian F Fifer RRT (Respir Care 1991;36:1218-1229)

$500 for Papers Based on 1991 OPEN FORUM Abstracts Submitted by Authors Who Have Never Published in RESPIRATORY CARE

1. Successful Ambulance Transport Utilizing High-Frequency Jet Ventilation. Kathleen Meyer RRT, Robert White MD, Linda Love RRT, Delores Tucker NNP, and Ross Havens RRT, Memorial Hospital of South Bend, South Bend, Indiana
2. Treatment of Status Asthmaticus with Albuterol Aerosolized Continuously. N Tate Bennett CRTT, Cape Fear Medical Center, Fayetteville, North Carolina
3. Rapid Analysis of Exhaled CO_2 To Assess Endotracheal Tube Placement. Sharon Leigh Day RRT, Larry Lewis Wooton RRT, and Neil MacIntyre MD, Duke University Medical Center, Durham, North Carolina
4. HFJV via a SCOOP Trach: A Case Report. Gregory Neil Foust RRT and Michael D Wilons MD, Baptist Memorial Hospital, Memphis, Tennessee

Funded by Radiometer America

Three awards of $333 each for the best features: (1) Test Your Radiologic Skill, (2) Blood Gas Corner, and (3) PFT Corner accepted for publication in RESPIRATORY CARE from January 1991 through December 1991.

Test Your Radiologic Skill—Radiographic Findings following Pediatric Blunt Trauma. Carol R Schermer BA and Frederick W Clevenger MD (Respir Care 1991;36:63-66)

Blood Gas Corner—Oxygenation of the Carbon Monoxide Poisoned Patient. John M Graybeal CRTT, Garfield B Russell MD, and John Basile RRT (Respir Care 1991;36:57-62)

PFT Corner—Pulmonary Consequences of I.V. Drug Use. Joseph E Ollivier RRT and Peter Baylor MD (Respir Care 1990;35:1065-1067)

THE NATIONAL BOARD FOR RESPIRATORY CARE—1992 Examination and Fee Schedule

CRTT Examination

EXAMINATION DATE:	MARCH 14, 1992
Applications Accepted Beginning:	November 1, 1991
Application Deadline:	January 1, 1992
EXAMINATION DATE:	JULY 18, 1992
Applications Accepted Beginning:	March 1, 1992
Application Deadline:	May 1, 1992
EXAMINATION DATE:	NOVEMBER 14, 1992
Applications Accepted Beginning:	July 1, 1992
Application Deadline:	September 1, 1992

RRT Examination

EXAMINATION DATE:	JUNE 6, 1992
Applications Accepted Beginning:	December 1, 1991
Application Deadline:	February 1, 1992
EXAMINATION DATE:	DECEMBER 5, 1992
Applications Accepted Beginning:	June 1, 1992
Application Deadline:	August 1, 1992

RPFT Examination

EXAMINATION DATE:	DECEMBER 5, 1992
Applications Accepted Beginning:	July 1, 1992
Application Deadline:	September 1, 1992

CPFT Examination

EXAMINATION DATE:	JUNE 6, 1992
Applications Accepted Beginning:	December 1, 1991
Application Deadline:	April 1, 1992

Perinatal/Pediatric Examination

EXAMINATION DATE:	MARCH 14, 1992
Applications Accepted Beginning:	July 1, 1991
Application Deadline:	November 1, 1991
Application Fee:	$150
Reapplication Fee:	$130

Fee Schedule

Entry Level CRTT—new applicant:	$ 90.00
Entry Level CRTT—reapplicant:	$ 60.00
RRT Written and Clinical Simulation—new applicant:	$190.00
Written Registry Only—new applicant:	$ 90.00
Written Registry Only—reapplicant:	$ 60.00
Clinical Simulation Only—new and reapplicant:	$100.00
Entry Level CPFT—new applicant:	$100.00
Entry Level CPFT—reapplicant:	$ 80.00
Advanced RPFT—new applicant:	$150.00
Advanced RPFT—reapplicant:	$130.00

	Active	Inactive
CRTT Recredentialing:	$25.00	$ 60.00
RRT Recredentialing:		
Written Registry Examination	$25.00	$ 60.00
Clinical Simulation Examination	$65.00	$100.00
CPFT Recredentialing:	$25.00	$ 80.00
RPFT Recredentialing:	$25.00	$130.00
P/P SPEC:	$25.00	$130.00

Membership Renewal: CRTT/RRT/CPFT/RPFT $ 12.00

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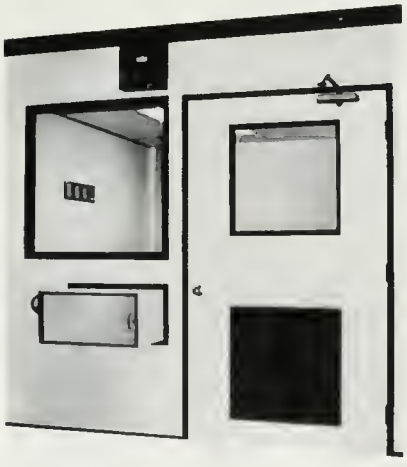
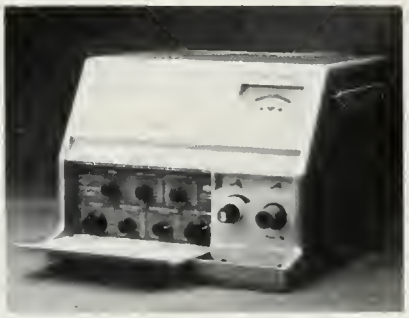
News releases about new products and services will be considered for publication in this section. There is no charge for these listings. Send descriptive release and glossy black and white photographs to RESPIRATORY CARE Journal, New Products and services Dept., 11030 Lane, Dallas TX 75229.

New Products & Services

PEAK FLOW METER. The Vitalograph Peak Flow Meter is designed to help asthmatics determine the degree of airway obstruction that they are experiencing. The device fits into pocket or purse and is easily sterilized, according to the manufacturer. The meter is manufactured by Vitalograph and marketed by Miles Pharmaceuticals. For customer service and to place orders, call (800) 992-1120. Mention RESPIRATORY CARE when you call.



ISOLATION ROOM. The Isol-Aide incorporates (1) separate air control to maintain negative pressure within, (2) HEPA filters, and (3) ultraviolet light, to reduce the risk of transmission of airborne diseases, according to the manufacturer. Units are prefabricated and factory wired for ease of assembly and relocation. Isol-Aide™ Component Systems Inc, Dept RC, 7000 Granger Rd, Cleveland OH 44131.



VERSATILE VENTILATOR. The Aequitron LP-10 ventilator is engineered to cost-effectively allow a patient to remain on the same ventilator for transport and rehabilitation in the hospital and on to the home or extended care facility. According to the manufacturer, the ventilator can be interfaced with monitors, oxygen blending systems, and printers. Aequitron Medical Inc, Dept RC, 14800 28th Ave N, Minneapolis MN 55447. (612) 333-6621.

FEEDBACK SYSTEM. The RFb respiration feedback system is said by the manufacturer to increase oxygen saturation and reduce dyspnea and oxygen requirements for the user. RFB Technologies, Dept RC, 5840 Town Bay Drive, Suite 217, Boca Raton FL. (407) 367-8611.

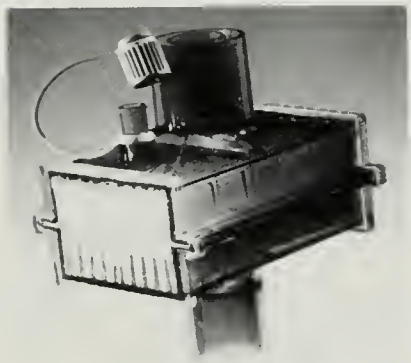
PORTABLE RESPIRATOR. The Tech-Safe Model SVC-25 is designed to contain nebulized medication and droplet nuclei produced during coughing, for protection of patients and caregivers. According to the manufacturer, HEPA and carbon filters provide for filtration and easy disposal, with a life of 1 to 2 years. Other features include a 250 cfm motor blower with magnehelic gauge to assure proper suction, 50 psi/15-liter compressor for nebulization, and a 25-ft, retractable power cord. Medicam Technologies Corp, Dept RC, PO Box 62, Hudson NH 03051. (603) 880-1462.

CATALOG. A 40-page catalog with detailed descriptions of products and services is available from ECRI, Dept RC, 5200 Butler Pike, Plymouth Meeting PA 19462.

QUICK COUPLERS. Plastic couplings with push-button disconnects that satisfy USP Class VI criteria are available for plastic tubing lines used for handling blood and other body fluids. A 36-page brochure describing the couple line of couplings and fittings is available. Contact Tom Talbot, Colder Products Co, Dept RC, 1001 Westgate Drive, St Paul MN 55114. (612) 881-5111.

PC-BASED SPIROMETER. The Zebra plugs into any personal computer's serial port and transforms any PC into a complete spirometry system, according to the manufacturer. Features of Zebra include Predicteds (with choice of 6 reference sets), pre- and post bronchodilator comparisons, real-time graphs, compliance with ATS standards, interpretation, trend analysis, inhalation challenge, quality control checks, and unlimited patient storage. Vacumetrics Inc, Vacumed Division, Dept RC, 5770 Nicolle St, Ventura CA 93003. (805) 644-7461.

AEROSOL HEATER. A built-in computer chip constantly controls temperature in the Prefil® Adjustable Electronic Aerosol Heater and can deliver 38°C aerosol to the patient's airway, according to the manufacturer. Power is controlled via a sensor probe at the patient's airway, and a large volume of heated mist of correct particle size plus vapor is delivered to the patient. An LCD displays airway-threshold temperature. Professional Medical Products Inc, Dept RC, PO Box 3288, Greenwood SC 29648.



HMEF WITH CO_2 PORT. The new Pall Heat and Moisture Exchanger Filter with CO_2 Monitoring Port provides heat, humidity, and filtration protection for intubated patients, protection for staff and equipment, and a port for monitoring end-tidal CO_2, according to the manufacturer. The monitoring port is equipped with a luer-lock cap that allows easy CO_2 measurement and is easily closed. Pall Biomedical Products Corp, Dept RC, 77 Crescent Beach Rd, Glen Cove NY, 11542. (800) 645-6578. In NY, (516) 759-1900.

EASY CAP ET CO_2. Nellcor Inc now markets as EASY CAP the FEF End-Tidal CO_2 Detector formerly sold by Fenem Inc. The single-use device weighs less than 1 oz and fits all standard airway connectors, according to the manufacturer. Nellcor Inc, Dept RC, 25495 Whitesell St, Hayward CA 94545-3618. 1-800-NELLCOR.

THE DEEP PICTURE ™. Radiometer, the world leader in blood gas analysis, has developed a new instrument that, for the first time, incorporates both blood gas and hemoximeter (CO-OX) measurements in one analyzer. In addition to the traditional blood gas measurements of pH, P_{CO_2} and P_{O_2}, the new ABL™520 also measures tHb, sO_2, O_2Hb, COHb, MetHb and RHb. This combination of parameters gives vital insight into a patient's acid-base and oxygen status, providing information on the oxygen uptake in the lungs, its further transport and release to the tissue. For complete information and a free brochure, contact Radiometer America Inc., 811 Sharon Drive, Westlake, OH 44145. Call toll free, 1-800-736-0600, ext 223.

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